

The University of Adelaide



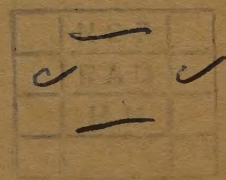
REPORT

of the

WAITE AGRICULTURAL RESEARCH INSTITUTE

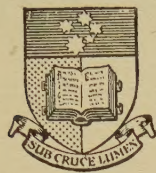
SOUTH AUSTRALIA

1958-1959



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THE WAITE AGRICULTURAL RESEARCH INSTITUTE
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CONTENTS

	Page
THE COUNCIL OF THE UNIVERSITY - - - - -	vii
THE STAFF - - - - -	ix-xii
INTRODUCTION - - - - -	1
THE WORK OF THE INSTITUTE	
Agronomy - - - - -	3
Agricultural Chemistry - - - - -	12
Plant Physiology - - - - -	24
Entomology - - - - -	30
Plant Pathology - - - - -	36
METEOROLOGICAL RECORDS - - - - -	41
PUBLICATIONS OF THE STAFF, 1958-1959 - - - - -	49
RECORDS OF FIELD EXPERIMENTAL WORK - - - - -	55

The University of Adelaide

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The Waite Agricultural Research Institute

STAFF (at 31st December, 1959)

Director: J. MELVILLE, M.Sc., Ph.D.

AGRICULTURAL CHEMISTRY:

Waite Professor of Agricultural Chemistry and Head of Department:
R. K. MORTON, B.Sc.Agr., Ph.D., F.A.A.

Readers:

Soil Science: J. P. QUIRK, B.Sc.Agr., Ph.D.

Virology: R. J. BEST, D.Sc.

Senior Lecturers:

Protein Chemistry: D. H. SIMMONDS, M.Sc., Ph.D. (Rural Credits Fund).

Plant Biochemistry: A. ADELE MILLERD, M.Sc., Ph.D.

Lecturers:

Enzyme Chemistry: M. R. ATKINSON, B.Sc., Ph.D.

Virus Chemistry: H. P. C. GALLUS, M.Sc.

Soil Chemistry: D. G. LEWIS, M.Sc.

Soil Science: J. W. MCGARITY, M.Sc.Agr., Ph.D.

D. J. GREENLAND, B.A., Ph.D. (State Wheat Fund).

Analyst: A. C. JENNINGS, B.Sc.

Laboratory Steward: H. R. J. LOVELOCK.

Graduate Technician: E. J. FREDERICK.

Senior Technical Assistant: CORALIE C. POTTER.

Technical Assistants: A. L. SPARROW, F. V. BOSTOCK.

Laboratory Assistants: M. P. RADIC, S. GARDONYI, R. A. ROBERTS, E. C. BESSANT, P. C. LEE, P. R. RAVENSCROFT.

Junior Laboratory Attendants: R. L. MECKLENBURGH, S. M. SMITH, K. W. J. CROCKER, R. CONNELLY, JANICE K. MYERS, MEREDITH LEMON, M. HOLLISTER.

AGRONOMY:

Waite Professor of Agriculture and Head of Department: C. M. DONALD, M.Ag.Sc.

Senior Lecturers:

Plant Breeding and Genetics: K. W. FINLAY, Ph.D.

Agronomy: J. N. BLACK, M.A., D.Phil., K. P. J. BARLEY, M.Agr.Sc.,
R. J. MILLINGTON, M.Sc., Ph.D.

AGRONOMY (*continued*)

Lecturers:

Botany: D. E. SYMON, B.Ag.Sc.

Agronomy: J. K. POWRIE, B.Sc.Ag., M.Sc.

Plant Breeding & Genetics: R. KNIGHT, B.Sc., Dip.Ag.Sc., Dip.Trop.Ag. (I.C.T.A.).

Cytology: K. ABELE, M.A., Ph.D.

Agrostology: J. H. SILSBURY, M.Ag.Sc.

Animal Production: W. G. ALLDEN, M.A. (Wool Research Fund).

Senior Technical Assistants: E. J. LEANEY, M. J. BARGE, V. KISIS.

Technical Assistants: R. W. MALLIN, A. V. LEHMANN, R. D. PEARCE, D. J. WILLIAMS, R. G. CAIN, R. HULA, J. MALONEY.

Laboratory Assistants: A. G. W. HEWSON, SALLY N. HARRINGTON, IRMA BUMBIERIS.

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ENTOMOLOGY:

Reader and Head of Department: D. C. SWAN, M.Sc.

Senior Lecturer: H. S. F. LOWER, M.Sc.

Lecturers:

B. JOHNSON, B.Sc.Ag., Ph.D.

K. M. DOULL, M.Ag.Sc.

D. A. MAELZER, M.Sc., Ph.D.

P. W. MILES, M.Sc., Ph.D.

F. D. MORGAN, M.Sc., Ph.D.

L. D. CRAWFORD, B.Sc. (Wool Research Fund).

D. J. TAYLOR, B.Sc., Dip.Ag.Sc., Dip.Trop.Agr. (Wool Research Fund).

J. MONRO, B.Sc., Ph.D.

Assistant Systematic Entomologist: HELEN M. BROOKES.

Technical Assistant: D. J. LAMBERT.

Laboratory Assistants: COLLEEN M. HILL, JOCELYN M. PEARCE.

Junior Laboratory Attendants: G. MEAVE MYLES, KAY C. SCHILLING, P. KAY JACKSON, PRISCILLA G. PEARSON.

PLANT PATHOLOGY:

Reader and Head of Department: N. T. FLENTJE, M.Sc., Ph.D.

Senior Lecturers:

Microbiology: J. H. WARCUP, M.Sc., Ph.D.

Plant Pathology: A. KERR, B.Sc., Ph.D.

Lecturers:

Plant Pathology:

N. C. CROWLEY, B.Sc.Agr., Ph.D.

M. V. CARTER, M.Ag.Sc.

B. G. CLARE, B.Sc.

Nematology: J. M. FISHER, B.Sc.Agr.

PLANT PATHOLOGY (*continued*)

Senior Technical Assistant: S. R. HOCKLEY.

Technical Assistant: LEA WICKMAN.

Laboratory Assistants: M. BUMBIERIS, HELENA M. STRETTON, GRETA L. MADIGAN.

Junior Laboratory Attendants: JANICE A. ROBERTS, GILLIAN FERRY, G. E. CAMPBELL.

PLANT PHYSIOLOGY:

Reader and Head of Department: L. H. MAY, B.Sc., Ph.D.

Lecturers:

Plant Physiology:

N. G. MARINOS, M.Sc., Ph.D.

L. PALEG, M.Sc., Ph.D.

D. ASPINALL, B.Sc., Ph.D. (Barley Imp. Fund).

Horticulture:

G. R. EDWARDS, B.Sc.Agr., M.Sc.

B. G. COOMBE, B.Ag.Sc., Ph.D.

Technical Assistant: A. W. ZANKER.

Junior Laboratory Attendants: JANETTE M. SINCOCK, FELICIA H. SMITH, G. McKNIGHT.

BIOMETRICS:

Reader: Vacant.

Laboratory Assistant: D. L. MESSENT.

CLERICAL AND LIBRARY STAFFS:

Secretary: G. L. GOODEN.

Librarian: SHIRLEY J. SUSMAN, B.Sc.

Library Assistants: MARY C. BIRD, PATRICIA M. HODGSON.

Secretary to Director: LAUREEN G. DOWNIE.

Secretary to Professor of Agricultural Chemistry: MARJORIE YOUNG.

Secretary to Professor of Agriculture: BERNADETTE T. MORRISON.

Secretary/Typistes:

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Department of Plant Pathology: LORNA M. SQUIRE.

Department of Plant Physiology: JUDITH S. DENNISON.

Typistes: JOYCE A. IDE, ROSEMARY C. SMITH, JESSIE M. YOUNG, JUDITH HANCOCK.

Telephoniste: BETTY J. LANGMAN.

Clerks: C. S. LEANEY, J. G. LEMERCIER, W. L. HARVEY.

PHOTOGRAPHER: K. P. PHILLIPS, A.R.P.S.

Junior Laboratory Attendant: PATRICIA J. ROSE.

FARM:

Manager: K. A. PIKE, R.D.A.

Senior Technical Assistant: D. B. STEEN, R.D.A.

Technical Assistant: A. W. DICK.

HEAD GARDENER: F. A. COUZENS.

MEMBERS OF STAFF ABSENT ON STUDY LEAVE DURING 1958-59:

C. M. DONALD, A. KERR, N. C. CROWLEY, J. H. WARCUP, R. J. BEST, N. G. MARINOS, K. W. FINLAY, N. T. FLENTJE, J. N. BLACK.

FULBRIGHT SCHOLARS:

PROF. J. B. HANSON (University of California).

Mr. C. F. BENNETT (University of Colorado).

POST-GRADUATE STUDENTS: L. A. G. AYLMORE, J. McD. ARMSTRONG, R. M. FAWCETT, J. R. WELLS, R. LABY, D. MONTAGUE, J. F. JACKSON, B. G. WILLIAMS, W. R. STERN, R. SCOTT-YOUNG, R. F. SEAMARK, G. KENNEDY, N. A. NAIDU, P. R. BIRKS, J. B. TAYLOR, R. L. DODMAN, W. J. MOLLER, J. NATH, M. A. ROSS, M. S. BUTTROSE, P. NICHOLLS.

MEMBERS OF THE STAFF WHO HAVE LEFT FOR OTHER APPOINTMENTS SINCE JANUARY 1ST, 1958:

A. F. JENKINSON, C. G. HANSFORD, J. H. COATES (Comm. Wheat Fund), H. V. JENKINS.

Duncan C. Swan, M.Sc.

READER-IN-CHARGE — ENTOMOLOGY DEPARTMENT,
WAITE AGRICULTURAL RESEARCH INSTITUTE

With the death of Duncan Campbell Swan in London on 26th December, 1960, science in Australia has sustained an untimely loss.

Born in Perth on 28th November, 1907, he spent his youth in Western Australia. After completing his secondary education at the Perth Modern School he proceeded to the University of Western Australia, where he gained an Honours Degree in science. He was awarded a Hackett Research Studentship and gained the Master's Degree in the University of Adelaide in 1935.

In 1931 Mr. Swan was appointed Assistant Entomologist on the staff of the Waite Agricultural Research Institute under the late Professor James Davidson. He became Senior Entomologist in charge of the Department of Entomology in 1946 and was promoted to Reader in 1955.

During World War II he served in the R.A.A.F. as Entomologist in charge of the malarial control campaign in Australia and New Guinea, attaining the rank of Flight Lieutenant.

After demobilization in 1946 he returned to duty at the Waite Institute, and in 1950 travelled overseas to study research development at several of the world's foremost institutions. Following his return his efforts were directed, on the one hand, to increasing the scope of entomological services to the State, and on the other to establishing fundamental research in a wide range of useful fields. He brought to this endeavour an encyclopaedic knowledge of the flora and fauna of terrestrial and marine Australia.

His special interests involved the grape *Phylloxera* on which he was the Australian authority. He showed that the biology and development of this pest in Australia differed significantly from that reported elsewhere. In the field of medical entomology and with particular reference to the Acarina he was consulted by workers both in Australia and abroad. Perhaps he will best be remembered for his work on the taxonomy and biology of the mites of horticultural importance. He had few peers as a technical illustrator and photographer. Unfortunately, his premature death leaves much of this work unpublished.

He continuously strove to produce the best possible conditions of space and equipment to meet the needs of a growing department. It is regrettable that he did not live to see the foundations laid for the new insectary which he had designed, modified and improved for more than a decade.

Mr. Swan's interest in library collections was evidenced in his long association as a member of the Committee of the Barr Smith Library and also the special library of the Waite Institute.

During his life he was active in societies allied to his scientific interests. He served for some years in various capacities in the Royal Society of South Australia, among which were two terms as Secretary, two as Vice-President, one as President, and five as a member of the Council.

Recently he was elected to the Royal Entomological Society of London.

Mr. Swan was held in high esteem by all who knew him as one who was kindly, sensitive, generous and charitable. By his staff in particular he will be remembered with gratitude for his selfless devotion to their scientific advancement and personal well-being.

The Waite Agricultural Research Institute

1. INTRODUCTION.

Previous reports have given an account of the foundation of the Institute and of the endowments and gifts which have played so significant a part in its development.

During the period under review considerable improvements in accommodation have been effected. The move of the major part of the C.S.I.R.O. Division of Soils to a new building brought relief to the Library, the Department of Agricultural Chemistry and the Administration Section. The remainder of the Division, viz. the Sections of Physics and Microbiology, are scheduled to move in 1961 when a second C.S.I.R.O. building will be completed, and this will afford further relief to overcrowded departments and sections.

With rising student numbers, both undergraduate and postgraduate levels, our lecture room and teaching laboratory space was becoming dangerously overcrowded. In 1958 the Government of South Australia agreed to the construction of a new Wing at the cost of £110,000, and this was occupied by the Departments of Entomology and Plant Pathology in August, 1959. As a result, the whole of the South Wing can be turned to student use, and from the beginning of the 1960 academic year there was available a further large biological laboratory, a chemical laboratory, and a lecture room, together with extra preparation space and common room.

From bequest moneys the Institute has also acquired another Field Laboratory of about 4,000 sq. ft. for pasture work and an Engineering Workshop of 3,670 sq. ft. A small Animal House has also been constructed.

The support given by various sectors of the agricultural industry is making a notable contribution to the research programme. In 1959 the Wool Research Committee provided £18,074, the Wheat Industry Research Council £23,021, the South Australian Wheat Industry Research Committee £3,250, and the Barley Improvement Committee £13,206. In addition to these funds which are derived from all over the Commonwealth, local groups of vegetable and fruit growers in the irrigated area of this State have imposed levies on production for the investigation of problems of specific interest to those regions.

Generous grants have been made by other institutions and individuals for special purposes. The Rockefeller Foundation of New York contributed £9,000 and the Anti-Cancer Fund £5,000 towards the cost of an electron microscope. The Rockefeller Foundation also granted £4,500 towards the cost and construction of a new Insectary, and this sum, together with contributions already received, notably by the Rural Credits Development Fund of the Commonwealth Bank, will enable the building to be started early in 1960.

Under the original deed of gift executed by Peter Waite, an area of about 12 acres was set aside as a University Sports Ground, and this has been administered by the Director of the Institute and the University Sports Association. Although the area has been used sporadically by a number of University clubs, money has never been available to turn the area into a first-class ground. It is pleasing to be able to report that over the past two years the University Sports Association has undertaken a vigorous improvement programme; the whole

area has been graded, an underground water reticulation system installed and connected both to the mains supply and to the dam, and an excellent turf established. Development will be completed with the erection of a sports pavilion.

2. THE TEACHING PROGRAMMES.

This sphere of activity of the Institute has continued to expand commensurately with that of other sections of the University of Adelaide. The five Departments at the Waite Institute provide most of the undergraduate training, at the third, fourth and fifth (Honours) years of the course for the degree of B.Ag.Sc. within the Faculty of Agricultural Science. Courses are given in the following subjects: Agricultural Biochemistry, Agricultural Botany, Agriculture, Agronomy, Biometry, Entomology, Horticulture, Microbiology, Plant Breeding, Plant Pathology and Soil Science. Certain subjects, of which the most important is Animal Production, are taken at the Roseworthy Agricultural College.

Honours and postgraduate teaching is undertaken in all Departments. The number of candidates has increased substantially during 1958 and 1959. In 1960 higher degrees were conferred on nine postgraduate students: B.Ag.Sc. with Honours (6), M.Ag.Sc. (2) and M.Sc. (1).

3. THE RESEARCH PROGRAMME.

The research programme of the Institute extends over a wide range of scientific disciplines underlying agricultural practices. Much of the work has its immediate origins in problems of significance in southern Australia, but the pursuit of these problems commonly carries the research into basic fields of general agricultural significance. A noteworthy feature of the great increase in contributions from the agricultural industries has been the recognition by the contributors of the claims of more basic studies in the spending of their funds. Indeed, the attitude of the Australian primary producer towards research is no longer one of scepticism, but of an almost embarrassing belief in the scientist and his potential to increase the volume and efficiency of production.

The Institute also provides specialist advisory services in systematic botany, plant pathology and entomology to the State Departments of Agriculture and of Woods and Forests. These services have reciprocal value to the Institute because they draw attention to problems facing these Departments and on which profitable research might be undertaken.

The research work of the Institute is organised within five departments: Agronomy, Agricultural Chemistry, Entomology, Plant Pathology and Plant Physiology, and the work of each of these departments is recounted in the following pages of the Report.

The Work of the Institute

Agronomy

The work of the Department continues to be directed towards problems of soil-plant and plant-animal relationships in the field. Though rainfall and nutrients are commonly the limiting factors in crop and pasture production in Australia, it is becoming realised that light and soil oxygen may also impose limits on growth. The research programme on competition for light has enabled a much fuller understanding of production in this environment, for during a large part of the growing season at Adelaide, light is commonly the principal factor and sometimes the sole factor for which competition is occurring. The effects of deficiency of soil oxygen supply occur under more specific conditions; they are especially apparent in the reduction in germination and growth of cereal crops when heavy rains follow seeding. At the Institute no less than 50 per cent. of the variation in cereal yields is due to the depression in yield caused by heavy post-seeding rains. The influence of nitrogen on cereals in the context both of leaching and of crop uptake and retention is a field which has been surprisingly neglected in the past but now claims the attention of the Department.

Selection and breeding work continue both with cereals and pasture species. A notable feature of the breeding work with wheat and barley is the use, very early in the programmes, of tests of grain quality. Though some of these are necessarily empirical (they include rate of germination, micro-malting tests, biuret test for nitrogen) they can be used far earlier in the programme and over a much greater range of material than can such tests as baking quality or performance in the malthouse. The assessment of pasture plants still presents major problems and though such attributes as summer dormancy can be used to cull the material, performance under grazing remains the substantial criterion of value.

Studies of animal production in this Mediterranean-type environment continue. It has been shown that sheep recover very fully from the period of post-weaning nutritional stress normal to this environment. On the other hand, there is a marked residual effect from under-nutrition in the pre-weaning period.

Various other projects have been continued and are described below.

1. PERMANENT ROTATION EXPERIMENT (C1).

This experiment, which was commenced in 1925 and has been supervised throughout this period by Mr. K. A. Pike, includes a comparison of ten systems of crop rotations in which the principal crop is wheat. A permanent plot of sown pasture is also maintained in the experiment. The mean yields for the period 1926-59 (both grain and total produce) together with the yields from the 1958 and 1959 seasons are given in Tables 1 and 2 on pages 55-58.

The number of years of record on which long-term means are based was standardised for all rotations in the 1952-53 Report. Several rotations, particularly those involving leys, have been in progress only since 1949 and full assessment of their value is not possible at present.

In previous reports the beneficial effect of broader rotations on the yield of wheat was shown to be of considerable magnitude, particularly if excessively wet conditions were experienced at seeding time.

The following table shows the yields of wheat for the 1958 and 1959 seasons from several rotations commenced in 1925:

Rotations	Yield in bushels per acre	
	1958	1959
Wheat continuously	10.3	0.8
Wheat, bare fallow	32.0	3.7
Wheat, peas	27.4	3.6
Wheat, oats, fallow	44.8	6.9
Wheat, pasture, fallow	53.8	6.2
Wheat, oats, pasture, fallow	55.8	10.6

Seeding conditions in 1958 were very favourable and the season was an ideal one for cereals, while 1959 was the driest year on record and the yields of all crops were the lowest recorded since the experiment was commenced. Under both sets of conditions the beneficial effects of the broader rotations were maintained. However, after a four-year ley the following wheat crops have been poor. It has been a feature in this and a similar experiment that wheat sown on to ploughed up long leys (4 to 6 years) has proved unsatisfactory over the treatment period.

2. SOIL FERTILITY STUDIES.

A programme of work is in progress including examination of soil physical and chemical aspects of fertility. Problems associated with both cereal cropping and pastures are being dealt with.

(a) *Response of Wheat to Applied Nitrogen.* Field results obtained on previous crop rotation experiments have shown relationships between apparent density of the soil, level of applied nitrogen, rainfall following seeding and the seasonal variation in grain yield of wheat. In seasons when heavy rainfall followed sowing it was accompanied by increased apparent density, reduced response to applied nitrogen, reduced establishment of plants and reduced grain yield.

Pot experiments have been carried out by Dr. R. J. Millington to assess the relative importance of the two major possible effects of heavy rainfall following sowing.

The action of rainfall following sowing may be twofold, firstly, in leaching soluble nitrogen out of the root zone of the immature plants, and secondly, in impairing soil aeration both by soil compaction and simple occupation of the pore space.

The effects of rainfall as a leaching agent of soluble nitrogen can be paralleled by experiments on the time of application of nitrogen. Sand culture experiments where the "background level of nitrogen was negligible were performed and gave results which showed the effects of nitrogen stress due both to variation in duration of stress and time of occurrence of the stress". The occurrence of mildew and the basal leaching treatment adversely affected growth, but, nevertheless, the experiment showed treatment interactions indicating that nitrogen nutrition during weeks 5 and 6 after sowing may have a major influence in final grain yield determination. Further experiments are in progress.

(b) *Soil Aeration and Wheat Yield.* In another series of experiments seeds germinating in sand were subjected to atmospheres of 1-2 per cent. nitrogen in oxygen for 0 to 10 days and assessment was made of the effects of impaired aeration during the pre-emergence phase on the subsequent grain yield. None of the aeration treatments resulted in seedling mortality, although reduction in "rate" of germination and stature of plants occurred. The grain yields showed little effect ascribable to aeration treatments. In the field, conditions of impaired aeration during the pre-emergence and establishment phase are accompanied by reduction in establishment and low crop yields. Since no seedling mortality occurred in the laboratory experiments, it might be inferred that if indeed seedling mortality in the field is due to impaired soil aeration, then the aeration conditions set up in the laboratory were not severe enough and that more severe treatments may have produced effects both on seedling mortality and grain yield. Further experiments are in progress.

(c) *Factors Influencing the Recovery of Fertiliser Nitrogen by the Wheat Crop.* In numerous field experiments less than half the applied nitrogen has been recovered by the wheat crop. Reasons for inefficient recovery are being examined by Mr. K. P. Barley, emphasis being placed on losses of fertiliser nitrogen associated with the growth of the wheat plant itself.

In the 1958 season, part of the nitrogen present in wheat, which had been well supplied with nitrogen fertiliser, disappeared from the crop between heading and maturity. In Bencubbin between 30 and 40 lb. per acre of nitrogen was lost. In the 1959 season, measurements were repeated on two varieties grown after a three-year ley; but, in this season, no loss of nitrogen occurred. Further work is being conducted to determine the conditions which can sometimes lead to loss from the crop.

Part of the nitrogen applied in fertilisers is rendered unavailable in the root zone by conversion to microbial material. A pilot experiment was conducted in the glasshouse in 1958 to compare the extent of immobilisation within the root zone of a cereal with that occurring within the root zone of a legume. A defoliation treatment was superimposed to determine whether a sudden check to growth increased the turnover of root material, and hence the influence of the plants on immobilisation.

(d) *The Influence of Soil Strength on Root Growth and on Seedling Emergence.* Experiments conducted in California, elsewhere in the U.S., and in Germany provide evidence that yields of field and of horticultural crops can be reduced by soil compaction which has resulted from wheel pressure and the action of cultivating instruments. It has not yet been possible to distinguish between the effects of poor air and water relations and the effects of the high mechanical strength of plough-pans and hard pans.

Although soil strength can be characterised by simple measurements, the tests cannot be used to predict plant performance until more is known about the work performance of plant roots and emerging shoots.

In 1959 a laboratory technique was developed for applying a wide range of known resistances to germinating seeds and to growing roots. Measurements are being made of the influence of the magnitude of a mechanical resistance on:

- (i) germination rate;
- (ii) rate of root growth;
- (iii) the time taken by root tips to resume growth after a resistance has been applied.

The rate of extension of root tips of *Zea Mays* was about halved for every two atmospheres increase in load. A limited amount of work has also been undertaken on the mechanism by which the root tip develops the pressure needed for growth against a resistance.

(e) *Fertility Status of Sandy Soils in South-Eastern South Australia.* In south-eastern South Australia large tracts of sandy soils of extremely low inherent fertility have been sown to pasture during recent years. The trend of fertility on these soils is a subject of considerable agronomic interest as well as practical importance. A study has therefore been commenced by Mr. J. K. Powrie of the accumulation of organic matter and inorganic plant nutrients and their disposition in the profile.

Soil analyses and preliminary pot and field trials have given support to more general observations that a large increase in the fertility of these soils occurs after a few years of vigorous pasture growth. Detailed investigation of this matter is proceeding.

(f) *Phosphate Requirement on Sandy Soils.* The use of substantial amounts of phosphate fertiliser is an essential feature of pasture production on the soils mentioned above. The cost of the annual dressing of fertiliser may be as much as 25 per cent. of the gross return during the early years following pasture establishment. For efficient pasture production on these soils an accurate estimate of phosphate requirement is needed.

The means for making such an estimate are being sought in a project begun in 1958. This work will provide information on the rate at which phosphorus accumulates in the soil following top-dressing and the effectiveness of this phosphorus for plant production as determined by chemical and positional factors.

In 1958 and 1959 a number of trials involving rate of application of phosphate were established on soils of varying phosphorus status and the yield response to the applied phosphate and the phosphorus uptake will be correlated with various measures of soil phosphorus fractions and their distribution in the profile. This project is being undertaken by Mr. J. K. Powrie in conjunction with Mr. A. C. Jennings of the Department of Agricultural Chemistry.

The results obtained thus far indicate that marked residual effects from applied superphosphate are obtained on these soils. Short-term studies have shown that on new land the initial superphosphate dressings have a residual value of about 50 per cent. in the following year. In other trials it has been found that where a total of half a ton of superphosphate has been applied to an area at normal top-dressing rates only very slight responses to phosphate can be detected in either cereal crops and pastures.

(g) *Comparative Studies on the Inorganic Nutrition of Pasture Species.* There is abundant evidence that plant species, and strains within a species, may show pronounced differences in their susceptibility to nutrient deficiencies. These observations suggest that there is prospect of achieving improvements in the efficiency of plant production by choosing or breeding varieties having lower fertiliser requirements than those in current use.

At present, studies are in progress of the nutritional requirements of a number of pasture species and varieties of importance in southern Australia. Preliminary studies have revealed some interesting results. For example, varieties of *Trifolium subterraneum* show marked differences in their susceptibility to deficiencies of several cations when these are induced by unfavourable cation

balance. The nature of these and other differences and their agronomic significance are under study.

(h) *Gas and Liquid Movement in Soils.* In conjunction with experimental work on soil-plant relationships studies have been made on permeability of soil to water and gas diffusion in soils. The permeability of porous materials to both liquids and gases has been investigated and using an "effective area" for transport equal to $\epsilon^{4/3}$ where ϵ is the porosity in cc per cc, most satisfactory agreement has been obtained between computed and experimentally determined permeabilities. The competition method is based on both summed pore area interactions and the pore radius interactions likely to occur in porous materials.

In gas diffusion in soils and porous solids a similar approach has been made, but there is lack of experimental data on which to test the method of computing diffusive flow. The computation method differentiates between the contributions made by both total porosity and gas-filled porosity and implies that for materials of differing total porosity but the same gas-filled porosity flow can be less in the material with the higher total porosity.

Apparatus is being constructed to continue experimental studies on gas diffusion in porous solid-gas and porous solid-liquid-gas systems. This work is being carried out by Dr. R. J. Millington in conjunction with Dr. J. P. Quirk, and is being extended to include ion diffusion studies.

3. INVESTIGATIONS IN CROP AND PASTURE PLANT PHYSIOLOGY.

(a) Studies by Dr. J. N. Black, mentioned in the 1956-57 report, had demonstrated the importance of the position of leaves of competing individual plants within a subterranean clover sward. The same concept was tested in an examination of the growth of mixtures of strains of subterranean clover, which vary markedly in morphology when grown under sward conditions. It was shown that strains whose leaves are held at the top of the canopy suppress those which have shorter petioles and whose leaves are thus maintained in the reduced light intensities of the lower layers of the sward.

A further study concerned the border effect in clover swards grown in large boxes, and objective evidence was obtained on the siting of areas to be sampled within boxes of various types.

(b) A visiting Fulbright Junior Fellow, Mr. C. F. Bennett, examined the time of onset of competition in clover swards, and it was found that competition between individual plants occurred at a very early stage in the development of the sward. It is not yet clear why competition should begin as soon as it does, and it is hoped to make further studies along these lines in due course.

(c) A study was made of the recovery of clover from varying periods of shading. Grass and clover were grown in alternate narrow panels to make up a mixed sward so that competition between species was confined to competition for light alone. Clover yield in mixed stands declined as the light intensity at the surface of the clover canopy was reduced. The clover panels which were transferred from mixed stands to a more favourable light environment progressively later in the experiment recovered from the effects of shading, but where the shading of clover by grass was so severe as to cause very heavy mortality, and extreme debility of the survivors, clover production was not restored, even after six weeks without shading.

(d) *Plant Growth in Controlled Environments.* A prototype plant growth cabinet has been constructed for studies requiring controlled environments. The

light source is a combination of mercury vapour lamps and daylight fluorescent tubes giving a light intensity of about 6,000 foot candles at working distance 1 foot from the top of the cabinet. Initial assessment of the cabinet has shown that temperature variation both in space and time has been limited to about $\pm 1^{\circ}\text{C}$. with wind speeds within the cabinet of the order of 1 m.p.h. Variation in light intensity over the plant platform was greater than expected due to positioning of ducts and this is being modified by additional lateral lighting.

4. BOTANY, PLANT INTRODUCTION AND PLANT TESTING.

(a) *Botany*. Taxonomic investigations and matters relating to the Herbarium, Arboretum and general botanical service are in the hands of Mr. D. E. Symon, Systematic Botanist.

During 1958-59 over 750 plants were identified and reported upon for the public and other departments and institutions. New plants recorded were *Digitaria aequiglumis* and *Axonopus affinis* from Adelaide suburbs, *Echium vulgare* from Clare and Mount Gambier, and *Sonchus arvensis* from Clare. In addition, the following species of *Oxalis* were also recorded as established in the State; *O. articulata* from Mt. Compass, *O. bowiei* from Gawler, *O. corymbosa* from the Barossa Weir, *O. hirta* from Victor Harbour and Meningie, *O. incarnata* in the Adelaide Hills and *O. latifolia* from the Adelaide suburbs.

Silver-leafed nightshade, *Solanum elaeagnifolium*, is now widely established in the State and in some areas, particularly north of Clare, exists in large colonies. *Amaranthus muricatus* also appears to be spreading both in suburban and country areas. It does not have an overseas reputation as a bad weed, but it is proving difficult to control.

A further three thousand specimens were incorporated into the Herbarium bringing the total number to 21,800. A large collection of spear grasses, *Stipa* spp., remains to be identified. When completed, almost all of the older accumulated specimens will have been dealt with. Steel cabinets were purchased for the storage of herbarium specimens.

There has been a continued demand for seed of the *Eucalyptus*, "Urrbrae Gem", and early reports indicate that young plants are growing well in a number of localities. Other tree seeds and plant material have been supplied as before to the South Australian Housing Trust, Woods & Forests Department, the Botanic Gardens and to private nurseries.

Some duplicate and/or depauperate trees have been removed from the Arboretum and further trees planted. The plantation of *Eucalyptus* in the Mallee block was extended. A particularly interesting flowering during the year was the tropical Golden Shower, *Cassia fistula*, a tree rarely seen south of Brisbane.

A successful Tree Planting school, organised by the Department of Adult Education, under the Chairmanship of Mr. D. E. Symon, was held at the Institute in March, 1959. There was a full attendance of 65 visitors.

(b) *Studies on Introduced Perennial Grasses*. (i) Mr. J. H. Silsbury's work has continued on perennial grasses recently introduced from the Mediterranean area with the objective of improving the range of species adapted to the climatic conditions of southern Australia.

Dactylis glomerata—Cockfoot is proving one of the most promising species since its Mediterranean ecotypes are highly persistent over the hot, dry summers. For example, at Jamestown, a country centre with a 17-in. average rainfall, plants

sown on a two-foot grid spacing, after three years, have shown 100 per cent. survival of certain Mediterranean lines compared with 8 per cent. for Aberystwyth S.26. Also at the Waite Institute in a sward trial, New Zealand cocksfoot virtually failed to survive the first summer after sowing, whereas six Mediterranean lines averaged 80-90 per cent. survival of established plants.

Superior summer persistence of Mediterranean cocksfoot is ascribed to the occurrence of summer dormancy. Factors controlling dormancy are not yet known, but it is clear that dormancy is not a response to moisture stress itself since in a field experiment two lines failed to respond to summer irrigation, remaining completely dormant over the summer period.

Five principal types of cocksfoot of contrasting heading date, tillering ability and degree of summer dormancy have been recognised and seed obtained from isolation plots. Under the identification of line numbers (Gl. 31-35), seed has been released to State Departments of Agriculture and other agencies for further testing and part has been used for establishing large seed multiplication plots on Martindale Estate near Clare.

(ii) *Lolium perenne*.—Present investigations have confirmed that the Mediterranean ryegrass collection does not contain any lines that are as drought-resistant as are many of the cocksfoots. However, yield determinations of clonal transplants of 27 lines of Mediterranean ryegrass at a six-inch spacing in small swards have shown the majority of them to be superior to the commercial strains "Clunes" and "Colac" in summer survival, and further, these introduced lines are capable of much higher yield in the second year. Thus an improved source of drought resistance in ryegrass appears to be available.

Six lines have been selected to represent the range of habit and maturity types in the collection. Individual plants were selected on a phenological basis and the yielding ability of clonal transplants in swards. Seed of these lines has been obtained from isolation plots and will be used for small plot experiments in 1960.

Detailed studies of tiller production and tiller survival in both Mediterranean and commercial strains of contrasting maturity times have shown that few tillers persist in the vegetative state over the dry summer period. Autumn regrowth comes largely from axillary buds at the base of the fertile tillers. Dry weight per plant during early stages of growth is highly correlated with tiller number per plant.

(c) *Grain Legumes*.—Further data on the yielding ability of introduced crop legumes has been obtained for the Waite Institute environment and at two country centres — Crystal Brook and Turretfield Research Centre. Considerable variation in the yield of different species and strains relative to White Brunswick peas has been found between years and sites. This variation can be partly accounted for by variation in total yield (grain plus herbage), but ability to set and mature seed as reflected in the seed/herbage ratio is also considered to be an important determinant of grain yield. *Lathyrus cicera*, for example, shows an extremely constant seed/herbage ratio, whereas the same ratio for *L. sativus* may vary fourfold between years. The possible causes of this differential behaviour is being investigated.

Lathyrus cicera has continued to yield as well or better than White Brunswick peas. Seed increase of this species has commenced. Two new lines of peas have marketing qualities similar to White Brunswick and are capable of yielding up to 25 per cent. more grain than that strain. Further testing of these lines is continuing and seed increase will be commenced in 1960.

5. PLANT BREEDING AND CROP GENETICS.

Breeding and genetic studies with cereals and perennial grasses have been further expanded during the past two years. Much of the initial programme of testing large collections of introduced material from many parts of the world is nearing completion. The second phase of this work involving the growing and selection of hybrid progenies in country areas has been initiated.

Specialised machinery and techniques for handling large numbers of small plots in country areas have been developed and successfully tested.

(a) *Cereals.*

(i) *Barley.* The original collection of 800 barley varieties has been assessed for physiological and agronomic performance at several localities for the past two years. A number of varieties worthy of more intensive assessment have been selected on the basis of this accumulated data.

Valuable information on the general and specific combining ability of barley varieties is being gained from the diallel experiments grown as an F_1 , and then as F_2 bulk populations in each of three years. Six varieties have been selected on the basis of their good general combining ability for yield and low grain nitrogen percentage. These six are being used as "tester" varieties in crosses with varieties in the collection shown to have desirable characteristics in country areas. Parental combinations having high specific combining ability will be used to produce hybrid populations for breeding purposes.

The rate and evenness of germination, or "germination behaviour" of barley seeds, which is an important characteristic in the malting process, has been shown by Dr. K. W. Finlay to be genetically controlled. This process appears to be only slightly influenced by environmental conditions prevailing during the maturation of the grain, except where soil moisture stress affects the plants during this period, when the subsequent rate of germination of this grain is markedly affected, although the relative differences between varieties remains about the same.

A simple mathematical formula enables a cumulative germination graph to be cited as a single numerical value, thus facilitating simple statistical analysis of results. This germination behaviour now can be assessed very early in a breeding programme.

Study of barley varieties and hybrids has shown soil moisture stress during the maturation of the grain to be one of the environmental characteristics of prime importance to yield and quality. A small number of varieties have been found which are relatively more stable under moisture stress, even in conditions of increased soil nitrogen fertility. These varieties are being used for further intensive investigation.

(ii) *Wheat.* A collection of some 3,000 wheat varieties from most wheat-growing areas of the world has now been assembled and assessed for a wide range of agronomic and physiological characteristics for three years at the Institute and one year in country areas. Further testing will be required to obtain a reasonable estimate of varietal response to a range of environments.

Three Australian varieties of wheat have been used as "tester" varieties in crosses with a range of material from overseas. These crosses have been made to give combinations having various percentages of Australian and "introduced" genes in the hybrids. This crossing programme is now complete and the hybrid material will be tested, in the F_1 and bulk F_2 generations, for yield, grain nitrogen content, small scale dough expansion and sedimentation.

A wide range of varieties from the collection is also being assessed for combining ability, using Australian varieties as "testers".

(iii) *Experimental Machinery*. To facilitate the handling of very large numbers of selection rows and small plots in country areas, machines have been designed and successfully tested to replace the hand sowing and harvesting usually associated with this part of plant breeding work.

Small Plot Seeder. A small plot seeder attachment for a tractor has been developed. The machine is self-cleaning and is fitted with magazine loading to facilitate easy handling of large numbers of varieties or hybrids in the field.

The "Finlay Seeder", as this machine has been named, is able to sow up to 1,200 10-foot rows of cereals per hour. Every row can be sown to a different variety or hybrid if necessary.

The machine is capable of sowing nine rows at a time and the length of row can be varied from 2 or 3 feet to over 100 feet. Sowing rate can be varied over a very wide range.

Small Plot Harvester. A small plot harvester using the "stripper" principle has been built using a rotary-hoe as the traction unit. This machine also is self-cleaning and harvests small 10-foot plots at the rate of 550 per day. The samples are threshed and winnowed during the harvesting operation.

(b) *Perennial Grasses*. The trial in which clonal derivatives of nine plants of *Dactylis glomerata* were compared, both under space plant conditions and in swards was completed in 1958. The results obtained by Mr. R. Knight from this trial showed that there was a very poor correlation in dry matter production and tillering between plants grown under the two spacing conditions. This trial provided further evidence that selection of grasses for yield characteristics should be carried out under test conditions similar to those under which the grasses will be used.

Two of the nine plants that were clonally propagated for use in this trial were of Northern European origin (U.K.) while the remainder came from countries bordering the Mediterranean. During the summer neither of the Northern European clones were dormant and 90 per cent. of the plants died in the swards. In contrast, the Mediterranean clones were dormant for the dry summer months and mortality was low, varying from 3-25 per cent. between clones. The full results and conclusions from this trial are being published.

The nine plants were hybridised in all combinations. Some of the families were grown during 1957 as spaced plants, but because of the conclusions reached from the trial mentioned above, the full 72 families were grown again during 1959 under sward conditions. This trial will last for two years and will provide data on the inheritance of desirable agronomic characters in this pasture grass.

(c) *Cytological Investigations*. The studies on chiasmata in *Dactylis* were continued and extended to additional races and their hybrids. The analysis of the data is in progress. A paper by Dr. K. Abele on synsytes occurring in *Dactylis* is being prepared for publication.

6. FIELD NUTRITION OF SHEEP.

The study of the relative effects on productivity of pre-weaning and post-weaning nutrition during the first year of life in autumn dropped Merino lambs has been continued by Mr. W. G. Allden.

In this experiment one group of lambs was raised from birth to 12 months of age in such a way as to ensure that during this period growth received no major check. Three other groups were subjected to nutritional stress either in the pre-weaning period (0-6 months) or the post-weaning period (7-12 months) or throughout the whole 12 months period. At the end of the first year the mean bodyweight of the four groups ranged from 44 to 78 lb. The bodyweight changes, frame growth and wool production of the experimental animals in the subsequent period have shown the residual effects of poor nutrition in the pre-weaning phases of life to be of greater significance than undernutrition in the post-weaning period. The bodyweight margins between the groups is being gradually reduced and at three years of age the weight difference between the two extreme treatments has been reduced to 11 lb. (cf. 34 lb. at age one year).

In an earlier experiment the significance of periods of nutritional stress in the post-weaning period of life upon the subsequent producing of young Merino sheep was studied, and it was shown that in later periods of improved nutrition such undernourished animals would attain a body size comparable with that of sheep whose earlier growth had been unrestricted. An experiment was undertaken to examine the bodyweight changes or pasture intake of undernourished sheep and their better fed mates during a subsequent period of improved nutrition. Due to adverse seasonal conditions this period of improved nutrition was, in fact, a period of undernutrition, but even so the weight difference of 12 lb. between the two groups was reduced to a small but non-significant margin within six months, and the herbage intake of the previously undernourished sheep (estimated from faecal outputs) was significantly greater than the other groups.

Agricultural Chemistry

This Department is concerned with chemical and physical processes affecting the soil, plant and animal. The Department, therefore, is responsible for teaching of Agricultural Biochemistry and Soil Science. The courses for these two subjects are given in the third and fourth years of the course, with courses leading to the Honours degree given in the fifth year.

The Department is mainly concerned with basic research, and thus aims to provide the fundamental knowledge on which economic applications always depend. The research in the Department during the two years under review has therefore been concerned with the following topics.

1. CHEMISTRY OF CELL GROWTH AND CELL DIVISION.

(a) *Free Energy of Hydrolysis of Adenosine Triphosphate and other Phosphorylated Metabolites.*

(Professor R. K. Morton and Dr. M. R. Atkinson)

Basic to modern knowledge of the cell is the understanding of the mechanisms whereby nutrients are metabolised and energy so derived is used for cellular processes. Despite numerous attempts to establish the free energy of hydrolysis of adenosine triphosphate (ATP), until recently the value was established only within the range 5-10 calories/mole at 25° C. and at pH 7. The $\Delta G'$ was there-

galactokinase

- The equilibrium of reaction (2) was calculated from measurements for the reactions:—

(3) Glucose-6-phosphate $\rightleftharpoons$ Glucose-1-phosphate, and
phosphatase

- since it has been established that the free energy of hydrolysis of glucose-1-phosphate does not differ significantly from that of galactose-1-phosphate, and the equilibrium constants of reactions (3) and (4) may be more accurately measured than that of reaction (2).

From published equilibrium studies involving ATP and other phosphorylated metabolites, $\Delta G'$ for most other phosphorylated compounds of biological importance were calculated for standard conditions. The studies show that there is a continuous range of values from glycerol-2-phosphate ($\Delta G', -2.3$ kcal./mole) to enol pyruvate-phosphate ($\Delta G', -12.8$ kcal./mole) at pH 7.0 and 25° C. in the presence of excess Mg^{2+} .

These values are useful for predicting the equilibrium constants of enzymic reactions in the cell, although they do not indicate anything about the rate at which these reactions would proceed.

(Professor R. K. Morton and Dr. M. R. Atkinson)

The literature relating to the enzymically-catalysed transfer of phosphate and phosphoryl groups has been reviewed. The survey emphasises the importance of phosphorylated compounds in cellular reactions. Phosphorylated compounds appear to be unique in combining a high kinetic stability with a large negative free energy of hydrolysis. The central role of adenosine triphosphate for activation of metabolites re-appears, despite the discovery of numerous other enzymic reactions dependent on other nucleotides.

With a reliable value for the $\Delta G'$ of hydrolysis of adenosine triphosphate (see above), it has been possible to calculate the free energy of hydrolysis of most other important phosphorylated metabolites. It is observed that the concentration of magnesium ion has a marked influence on the free energy of hydrolysis of many such compounds and this may have important biological implications.

(c) *The Biosynthesis and Metabolism of Pyridine Nucleotides.*

(Professor R. K. Morton, Dr. M. R. Atkinson, Mr. J. Jackson
and Miss E. Johnson)

It has been shown by Morton and co-workers that CoI-pyrophosphorylase, an enzyme essential for biosynthesis of coenzyme I (β -nicotinamide adenine

dinucleotide), is localised in the nucleus in animal cells. Further studies have been directed towards elucidating the enzymic mechanism involved in biosynthesis of coenzyme I.

CoI-pyrophosphorylase has been purified over 1500-fold from crude preparations of pig-liver nuclei. The purified enzyme catalyses adenylation to both β -nicotinamide nucleotide and β -nicotinic acid nucleotide. The enzyme is inactive with α -nicotinamide nucleotide. The adenylation of β -nicotinamide nucleotide has been investigated over the pH range 4 to 11. Dixon's plots of pK_m and V_{max} against pH show a discontinuity in the pK_m /pH plot at about pH 5.8. This corresponds with the dissociation of the phosphate group of β -nicotinamide nucleotide. A further dissociation at about pH 9.9 has been attributed to a tyrosyl residue in the enzyme protein. Since V_{max} shows no discontinuity over the pH range studied, it is clear that there is charge neutralisation in the enzyme-substrate complex. K_m values for pyridine nucleotides decrease in the order: pyridine nucleotide > nicotinic acid nucleotide > nicotinamide nucleotide, indicating involvement of H-bonding in the formation of the enzyme-substrate complex. From these observations, a plausible mechanism for the enzymic reaction has been formulated.

It has been shown that a number of metal complexing agents, as well as alkylating agents, are inhibitors of purified CoI-pyrophosphorylase. These inhibitors include a number of well-established cytotoxic agents. The biological effect of these compounds may be due to the inhibition of synthesis of coenzyme I arising from the inhibition of CoI-pyrophosphorylase.

Improved methods have been developed for estimation of both the oxidised and reduced forms of coenzymes I and II in animal tissues. The methods for extraction of these compounds from tissues have been critically examined, since the compounds may be interconverted, or destroyed, during extraction from tissue. Specific enzymic methods for the accurate estimation of each compound have also been developed. The work is being extended to include other pyridine nucleotides which are precursors of coenzymes I and II. In this way it is hoped to be able to establish the dynamic relationship between the dietary source (nicotinic acid, or nicotinamide) of pyridine derivative and the enzymically-active coenzymes. This knowledge is essential for understanding of the interaction between nucleus and cytoplasm, especially in relation to the division process. Studies are also being extended to include measurements of coenzyme levels in the ruminant animal, as compared with the non-ruminant; and in animals suffering various metabolic disturbances, such as those associated with alloxan-induced diabetes and with liver damage induced by specific hepatoxins.

Since nicotinic acid nucleotide is required for enzymic studies of biosynthesis of coenzymes I and II, methods have been developed for the synthesis of nicotinic acid nucleotide and of nicotinic acid adenine dinucleotide from coenzyme I. Hitherto, nicotinic acid mononucleotide was only obtainable by isolation from yeast. The conditions have now been defined for deamidation of nicotinamide nucleotides using nitrous oxide with good yield of the desired product (nicotinic acid mononucleotide).

The effect of inhibitors of CoI-pyrophosphorylase on growth of tumours in rats and mice, as well as on the development of normal animals, is being investigated. It has been shown that nicotinamide may act as a non-toxic inhibitor of mitosis in growing onion roots and other workers have shown inhibition of mitoses in regenerating liver and in fertilised oocytes by this compound.

(d) *Comparative Composition of Deoxyribonucleic Acid*

(Dr. M. R. Atkinson)

It is possible that the differences between the morphologically-distinct groups of living organisms is reflected in the base composition of the deoxyribonucleic acids. The ratio of guanine/adenine has been determined for different animals. The results were as follows:—

Echidna (*Tashyglossus aculeata*), 0.92 ± 0.01 ;
sleepy lizard (*Tibiqua rugosa*), 0.82 ± 0.02 ;
rat (*Rattus rattus*), 0.75 ± 0.02 ; and
brush possum (*Trichosurus vilpecula*), 0.65 ± 0.01 .

These results provide further evidence of the biochemical dissimilarity of monotremes and marsupials.

(e) *The Fungal Branching Factor Exuded by Radishes*

(Dr. M. R. Atkinson and Dr. N. T. Flentje, Dr. A. Kerr
and Mr. R. Dodman (Plant Pathology))

It has been observed by Flentje and co-workers that exudates from roots of certain plants induce marked changes in the branching habits of certain soil-borne root-rot fungi. An active material was obtained from radish roots. This was fractionated by ion-exchange chromatography and by electrophoresis. A derivative of nicotinic acid was identified from its characteristic light-absorption spectrum. This material is being further purified so that its structure can be elucidated. It has been shown that N-methyl nicotinic acid causes the characteristic fungal branching *in vitro*.

2. PROPERTIES OF CYTOCHROMES AND RESPIRATION OF AEROBIC TISSUES.

(a) *Structure, Activity, and Mechanism of Action of Cytochrome b_2 (Lactate Dehydrogenase) of Baker's Yeast.*

(Professor R. K. Morton, Mr. J. McD. Armstrong and Dr. J. H. Coates)

Morton and co-workers crystallised cytochrome b_2 from baker's yeast and showed that it was a unique flavohaemoprotein having L(+)-lactate dehydrogenase activity. In the present studies, it has been shown that the riboflavin phosphate (FMN) prosthetic group is bonded to the protein portion of the enzyme via a sulphydryl group (cysteine residue) of the protein. Oxidation of the —SH group by oxygen is rapid and causes displacement of the flavin group and loss of enzymic activity. However, the haem group is firmly bonded to the protein.

The oxidation of —SH groups by oxygen causes aggregation of the protein. Whereas a single symmetrical component was detected in cytochrome b_2 maintained under oxygen-free nitrogen, after exposure to air two additional new components were detected with an analytical ultracentrifuge. Oxidation of the —SH groups, and formation of aggregates, was prevented by p-chloromercuri-sulphonate, and by N-ethyl maleimide.

Kinetic studies of the reduction of ferricytochrome c , dichlorophenol indophenol, and ferricyanide have been carried out over a range of substrate and acceptor concentrations. These studies show that the reduction of ferricyanide involves direct reaction with the flavin prosthetic group. In contrast reduction

of ferricytochrome *c* involves the haem group of cytochrome *b*₂ as an essential intermediary. It is possible to artificially modify cytochrome *b*₂ so that the rates of reaction with various hydrogen acceptors differs considerably from those of the native enzyme.

The sedimentation properties of ferrocytochrome *b*₂ have been investigated with an analytical ultracentrifuge. From these studies, $S_{20, w}^{\circ}$ has been found to be 8.36 svedbergs. However, in extensive studies using the approach-to-equilibrium procedure, great variability was found in the calculated molecular weight, due to apparent variation in the diffusion coefficient of the protein. The results suggest that cytochrome *b*₂ may exist as a dimer of molecular weight about 160,000, although other polymeric forms may also exist under different experimental conditions. The diffusion coefficient is now being estimated with conventional diffusion apparatus.

From these studies, a mechanism for the catalytic activity of this unique crystalline flavohaemoprotein has been formulated.

(b) *Comparative Properties of Cytochrome c from Yeast and Heart-muscle*

(Professor R. K. Morton, Mr. J. McD. Armstrong, and Dr. J. H. Coates)

Cytochrome *c* was first isolated from yeast, and later from heart-muscle. However, most studies have been carried out with material of animal origin. Cytochrome *c* was isolated from air-dried baker's yeast and purified by chromatography on ion-exchange resin (IRC 50). Treatment with trichloroacetic acid was rigorously avoided. The material so obtained was homogeneous on examination by electrophoresis and by sedimentation behaviour.

The electrophoretic mobility of the yeast protein was examined over the pH range 4 to 11. The material remained homogeneous at all pH values. The plot of electrophoretic mobility/pH showed that the iso-electric point was 9.6. Heart-muscle cytochrome *c* has an iso-electric point of 10.5, and has three additional molecules, of lysine per molecule of protein, as compared with yeast cytochrome *c*. This may well account for the differences in electrophoretic mobility.

In yeast cytochrome *c*, the peaks of the absorption bands (α , β , and γ) were found to be shifted by about 1 $m\mu$ toward the blue as compared with those of heart-muscle cytochrome *c*.

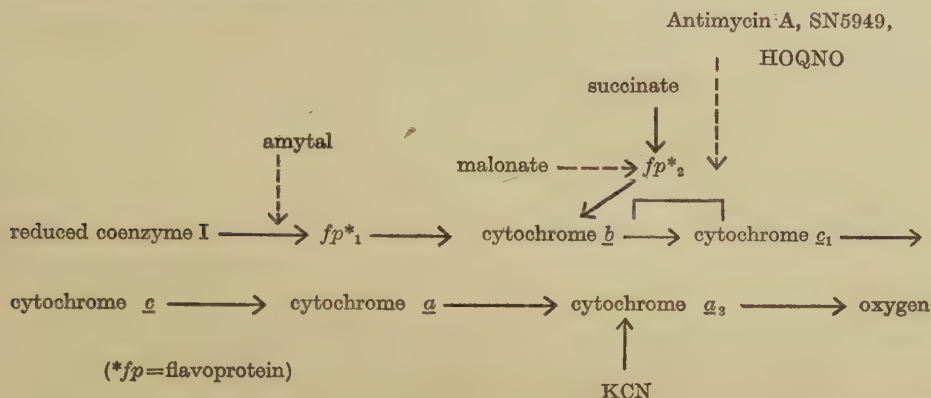
These results indicate that there may be considerable chemical differences between homologous haemoproteins from differing species of organisms.

(c) *The Respiratory Chain of Beetroot Mitochondria*

(Professor R. K. Morton, Dr. R. N. Robertson and Mr. J. Wiskich,
C.S.I.R.O., Plant Physiology Unit and Botany Department,
University of Sydney)

The respiratory chain of plant mitochondria contains a number of cytochrome components which are related to but not identical with those of animal mitochondria. The relationship between the components of the respiratory chain in beetroot mitochondria has been investigated with specific substrates and inhibitors, [antimycin A, 2-heptyl-4-hydroxyquinoline-N-oxide, 2-hydroxy-3-(2-methyloctyl)-1-4-naphoquinone, 5-ethyl-5-*iso*-amyl barbiturate, phenylurethane and ethanol].

From these studies it is concluded that the respiratory chain may be represented by the following diagram.



The terms "cytochrome b ", "cytochrome c " are used to represent specific haemoproteins which may be recognised by their specific spectral characteristics. However, it cannot be assumed that these haemoproteins are identical with the homologous haemoproteins of animal mitochondria. Studies of other workers suggest that ubiquinone is also a component of the respiratory chain, probably occurring between cytochrome b and cytochrome c_1 . In the diagram above, the dotted lines indicate the sites of action of various respiratory inhibitors.

In further studies, it has been found that the disulphide form of α -lipoic acid (2-6-dithio-n-octanoic acid) is a potent inhibitor of the oxidation of reduced coenzyme I, whereas it slightly stimulates oxidation of succinate and of ferricytochrome c . This compound thus has unique properties, not previously found for any component of the respiratory chain. The action appears to be due to a specific effect of the disulphide on the flavoprotein system which mediates hydrogen (electron) transfer from reduced coenzyme I to cytochrome c .

(d) *The Effect of Fungal Infection on the Respiration of Barley Leaves*

(Dr. A. Millerd)

It has been shown by Millerd and co-workers that there is a marked increase in the respiration of barley leaf during infection with powdery mildew, *Erysiphe graminis* var. *hordei*. Some uncoupling of oxidative phosphorylation in the leaf appears to occur. An examination is being made of the factors controlling respiration in mature leaf tissue, for which photosynthetic phosphorylation may largely provide the energy requirements. A number of compounds which appear in the infected leaf, but not in normal leaf, have been detected and these are being isolated and identified.

3. THE METABOLISM OF *OXALIS PES-CAPRAE*

(Dr. A. Millerd, Professor R. K. Morton and Mr. J. Wells)

Oxalis pes-caprae ("soursob") is an annual weed prevalent in arable land in the Adelaide plains. It accumulates up to 14 per cent. (dry weight basis) of oxalic acid in leaves and petioles. Control by normal weedicides or by

agronomic practices has not proved effective. To provide fundamental information which may lead to specific chemical control of this plant, studies are being made of the enzymic pathways of oxalic acid formation.

Initially, the isocitritase activity of bulbs, roots, leaves, and petioles was examined. Isocitritase was either absent or had very low activity in all material investigated. It appears improbable, therefore, that glyoxylate, the most likely precursor of oxalic acid, arises by cleavage of isocitrate by isocitritase.

In further experiments, plants were injected with ^{14}C -glyoxylate and ^{14}C -oxalate. The organic acid fractions, as well as sugars and amino acids, have been separated by chromatography. The distribution of the radioactive isotope is being studied to determine the metabolites arising from these compounds.

4. CHEMICAL STUDIES OF MATURE AND DEVELOPING WHEAT GRAIN

(a) *The Amino Acid and Protein Composition of Wheat Flour in Relation to Baking Quality*

(Dr. D. H. Simmonds)

The technique for estimation of amino acids in hydrolysates of proteins by separation on ion-exchange columns has been extended. An automatic machine has been constructed capable of handling nine columns simultaneously. The percent transmittance of the coloured compound formed by reaction between the eluted amino acid and ninhydrin is converted to optical density units and printed out by a simple digital print-out recorder. In this way a record is obtained of the amount of each amino acid in each eluate from each column. Subsequent summation of optical densities, and subtraction of the blank reading, gives the amount of a particular amino acid in each hydrolysate.

With this machine, results in good agreement with published values have been obtained with a reference sample of pure insulin. The amino acid composition of pure bovine submaxillary mucoprotein has been determined in association with Dr. A. Gottschalk (Australian National University).

The amino acid composition of a range of mature wheat and flours therefrom has been determined. The results show that there is a significant correlation between the amount of lysine and baking quality of the flour.

These studies have been extended to obtain the amino acid composition of individual proteins separated from flour. After removal of lipids with *n*-butanol, buffer-soluble proteins were extracted with sodium pyrophosphate at neutral pH and the proteins separated on columns of diethylaminoethyl- and carboxy methyl-cellulose columns. Six protein fractions have been separated from the buffer-soluble group. These are being further purified.

(b) *Physico-chemical Studies of Protein of Wheat Flour*

(Dr. J. H. Coates and Dr. D. H. Simmonds)

Proteins separated from wheat flour as described above were studied by electrophoresis and in an analytical ultracentrifuge. These studies showed that some of the fractions which appeared to behave as a single protein component by ion-exchange chromatography were heterogeneous by other criteria. There appears to be a relationship between electrophoretic mobility of the buffer-soluble protein fraction obtained by column chromatography and the ionic strength of the buffer required for elution from the column.

(c) *Studies of Developing Wheat Grain*

(Professor R. K. Morton and Mr. A. C. Jennings)

Information is required concerning the dynamic relationships between the various components of developing grain. Methods for the mechanical separation of immature grain into its major morphological fractions (pericarp, endosperm and embryo) have been developed to enable isolation of protein and other components of the developing grain.

The gross chemical changes occurring in each of the principal morphological fractions of the grain have been studied in two varieties ("Gabo" and "Insignia") harvested from field plots. The results of these comprehensive studies emphasise the importance of the testa-pericarp fraction in relation to nutrition of the developing endosperm.

A number of plants of each variety were injected with ^{14}C -labelled acetate at mid-flowering. Grain was harvested at seven intervals between fertilisation and mature grain stage. The various chemical fractions from this developing grain, especially the buffer-soluble proteins, are being studied. The results will be used to obtain information concerning the dynamic relationships between the various chemical components of the developing grain. Special attention is being given to the relationship between the buffer-soluble and the gluten proteins.

5. PHYSICO-CHEMICAL STUDIES OF CLAYS AND SOILS

(a) *Physico-chemical Aspects of Soil Aggregate Formation, and the Mechanism of Action of Stabilising Compounds*

(Dr. J. P. Quirk, Dr. D. Greenland, Mr. R. Laby and
Mr. B. G. Williams)

These studies are concerned with the factors which determine stability of soil aggregates. In initial studies, it was shown that the action of certain polymers (polyvinyl alcohol, polyvinyl pyridinium iodide, and polyacrylic acid) is due more to their high molecular weight than to their charge properties. These polymers appear to stabilise soil aggregates by strengthening the coarser pores (especially those with radii between $15\text{--}20\ \mu$) against failure. The molecular weight of the compound has a marked effect on the amount of polymer adsorbed.

The adsorption of cetyl pyridinium bromide by a variety of pure clay minerals has also been investigated. Four cetyl pyridinium molecules are adsorbed on each cation site of a clay. It appears that the cetyl pyridinium ion is adsorbed initially and subsequent adsorption is due to the condensation of three molecules around this to give a double layer of adsorbed molecules on the clay surface. From X-ray evidence, it appears that cetyl pyridinium is adsorbed on to sodium montmorillonite in such a way that the cetyl chains are parallel to the surface until all the cation exchange sites are filled. On further adsorption beyond this point the crystal spacing jumps from 20 to 42 angstroms, indicating that the chains are then perpendicular to the surface. This investigation has now been extended to include the study of adsorption of ethyl, butyl, octyl and dodecyl pyridinium bromides.

It is established that much of the organic nitrogen of soils occurs as amino acids which are in complexes with other compounds. Nevertheless, the amino-

and carboxyl- groups remain functional. An examination is therefore being made of the adsorption of amino acids, and of peptides by clay minerals.

Studies are also being carried out to elucidate the nature of the bonding between organic molecules and inorganic soil colloids, using polyvinyl alcohols, simple alcohols, polysaccharides and sugars.

(b) *The Mechanism of Clay Swelling and Clay-Water Relationships*

(Dr. J. P. Quirk and Mr. L. A. G. Aylmore)

An extensive study of the effect of hydrostatic suction and osmotic pressure of the external solution on clay swelling has been carried out. Three clay minerals, kaolinite, illite and montmorillonite saturated with sodium, potassium, calcium and magnesium have been studied.

To interpret the results a model for the clay mass has been devised. In this model the clay crystals are imagined as existing in oriented packets or domains with pores distributed throughout the clay matrix. When a clay material swells, as well as separation of the clay plates, there is a proportional increase in the pore volume and this has been described as pore swelling. This model has greatly facilitated the interpretation of swelling data and has enabled the calculation of the water film thickness associated with clay surfaces. Marked differences in the film thickness for sodium and calcium clays have been noted. For calcium systems the results indicate that a diffuse double layer is not formed. This work is at present being extended to the swelling of natural soils.

Adsorption equipment has been built up to enable the determination of surface areas and pore size distribution by the adsorption of nitrogen onto the clay materials at liquid oxygen and liquid nitrogen temperatures.

A large volume of pores with a Kelvin radius of 15 angstroms has been found in the materials examined. This lends support to the model proposed.

(c) *Use of Gypsum in Solution for Establishment of Pastures on Sodic Soils*

(Dr. J. P. Quirk and Mr. J. L. Davidson (C.S.I.R.O., Deniliquin))

The reclamation of alkali soils depends on replacement of sodium cation by calcium. For this purpose gypsum is normally used. The economic reclamation of large areas of land in the Riverina district of New South Wales depended on finding a more effective utilisation of gypsum than that normally obtained. It was found that addition of 5 cwt. of gypsum to the initial irrigation of 3 inches (viz. 10 me Ca/litre) flocculated the colloids and prevented formation of hard surface crust through which plants may emerge only with difficulty. This has ensured successful establishment of pastures. In this approach the emphasis has been on flocculation of the clay colloid, rather than on the exchange of sodium for calcium cation.

(d) *Negative Adsorption of Chloride Ions*

(Dr. J. P. Quirk)

Work on the negative adsorption of kaolinite suspensions has continued and the positive charges reported earlier for a soil kaolinite at high pH appears to be a general feature of the kaolin minerals, including halloysite. The extent

of the positive adsorption can be used to estimate the edge face area since the chloride is adsorbed onto terminal aluminium ions. The agreement between edge face area obtained in this way and from electron micrographs is good.

Studies with sodium montmorillonite have yielded interesting results with respect to negative adsorption and flocculation behaviour of this clay. When experiments are carried out at pH 8 an area of 400 m²/g is obtained; if, however, the pH is adjusted to below 5 before the determinations are carried out the full surface area of 760 m²/g is obtained. It is suspected that small quantities of aluminium are involved and that these are not readily exchangeable until the pH is lowered. In the course of this work it was noted that the point at which stable suspensions of sodium montmorillonite flocculated was extremely dependent on the previous acid treatment, suggesting that when aluminium is dissolved from edge faces there is no longer appreciable positive edge to negative face flocculation.

6. STUDIES OF SOIL PHOSPHATES IN RELATION TO PLANT NUTRITION

(a) *The Release of Phosphate from Soil Binding Sites, and Uptake by Wheat Plants*

(Mr. D. G. Lewis and Dr. J. P. Quirk)

A soil naturally deficient in phosphorus was treated with varying quantities of calcium phosphate solution and the uptake of phosphorus by wheat plants grown on the treated soils was followed. Under controlled environment conditions in a growth chamber it was found that during the period up to flowering the rate of uptake was almost constant for each soil and the magnitude was related to the total initial addition. Thereafter the rate decreased. The maximum rate of uptake of 25 micrograms of phosphorus per plant per hour is similar to that obtained in solution culture. It follows that phosphate must be released from the solid phase into the soil solution at a rate sufficient to allow the plant roots to absorb this quantity of phosphorus.

The retention of phosphate by clay minerals and some accessory minerals has been studied over the pH range 2-8. The results show that kaolinite is the most important of the clay minerals in soils for fixation of phosphate. There is close correspondence between the maximum adsorption for phosphate in dilute solutions ($< 1 \times 10^{-2}$ M H₂PO₄⁻), and for chloride, suggesting that the edge face of kaolinite crystals are the most important sites for phosphate adsorption under natural conditions.

(b) *The Effect of Soil-Water Stress on Nutrient Uptake*

(Dr. J. P. Quirk, Mr. D. G. Lewis and Mr. R. G. Fawcett)

The effect of increasing soil-water stress on phosphate uptake by young wheat plants and wheat seedlings has been studied. In some experiments, ³²P was used as a tracer. Investigations over a wide range of water content showed that soil-water stress did not influence the uptake of H₂PO₄⁻ ions until the adsorbing system of the plant was damaged by wilting.

The results suggest that plants obtain their water from coarse pores, and their phosphate requirements from the fine pores within the soil.

7. PHYSICAL STUDIES OF SOILS

(a) *Studies of Permeability of Porous Media, and of Ionic and Gaseous Diffusion in Porous Media*

(Dr. R. J. Millington (Agronomy Department) and Dr. J. P. Quirk)

An equation has been developed for the calculation of saturated and unsaturated permeability of inert materials. This equation uses the porosity and pore radius as derived from water desorption and mercury injection results. Good agreement between experiment and theory is found over the permeability range 10^{-6} to 10^{-15} cm².

Consideration has been given to the permeability of sandstones and limestones where the porosity is decreased by the consolidation and the precipitation of cementing substances in the pores of the inert matrix.

When the "r²" terms are omitted, the equation has proved satisfactory for the description of diffusion of ions and gases in porous media.

8. CHEMISTRY OF PLANT VIRUSES

(a) *The Nature and Properties of Tomato Spotted Wilt Virus*

(Dr. R. J. Best)

Studies of the purification of this virus have been continued. Differential centrifugation, with aqueous density gradients, has been used. Loss of infectivity during purification seems to be due to separation of the protein and nucleic acid portions of the virus. However, with present techniques > 80 per cent. of the activity is recovered in the final material.

(b) *Studies of Genetic Recombinants of Strains of Potato Virus X*(Dr. R. J. Best, Ir. A. Rozendaal (Wageningen) and
Ir. D. van Slogteren (Lisse))

The work was begun when one of us (R. J. Best) was the guest of the Virology Department of Professor Dr. T. H. Thung in the Agricultural University of Wageningen, Netherlands. It had been demonstrated in our laboratories in Adelaide that strains of Tomato Spotted Wilt Virus reacted in mixedly infected plants to form genetic recombinants. It was of special interest to find out whether a rod-shaped virus would behave in the same way. Potato Virus X was chosen for various reasons, including the following: It is a relatively stable virus biologically and chemically and can be obtained in a chemically pure form. It also gives rise to anti-sera and so there is the prospect of using serological and chemical markers; it has a world-wide distribution, and is the cause of one of the world's economically most important plant diseases.

Strains of Potato Virus X were chosen from stocks maintained in potato plants by Ir. A. Rozendaal at Wageningen, and of four strains tested three (1, 3 and 4) were retained for further work. The strains were purified biologic-

ally by limit dilution techniques. A search for markers (or characters) suitable for the investigations was successful and these are listed in the following table.

Table to illustrate genetic markers by which some strains of Potato Virus X may be distinguished.

Indicator plants and markers						
Strain	Tobacco		N. glutinosa		Tomato	
	Pr.*	Sy	Pr	Sy	Pr	Sy
1	—	C	—	—	NIP	—
2	Yd	+	low temp: NIP high temp: WRS	fast mottle and NI	NIP	—
3	NldP	—		slow mottle and slight NI	NIP	Net C Nlp stem bending

*Pr=primary; Sy=systematic; C=chlorosis; Yd=yellow disk; NI=leaf necrosis; P=pigmentation; d=in form of a disk; WRS=white ring spot.

The above table was constructed from data obtained by using virus derived by the single-lesion at limit-dilution technique (1 in 50,000) for strains 3 and 4 and the limit-dilution of systemically invaded tissue for the mild strain 1. The search for serological markers is still in progress, and chemical investigations will be pursued if stage 2 reveals the presence of genetic recombinants.

Stage 2: Recombination Experiments. The mild strain 1 and severe strain 4 were applied to test plants as a mixture, first in equal amounts of infective sap and, in a later experiment, in serologically equivalent concentrations. In both cases there was a strong interference effect on the strains, as judged by comparison with the indicator plants that had received the pure strains singly. However, the search for recombinants was incomplete at the time of the departure of one of us (R. J. Best) and arrangements are being made to continue the investigations as an international co-operative venture, the laboratories at Adelaide, Lisse and Wageningen each taking part.

9. STUDIES OF ANALYTICAL PROCEDURES

(a) *Mechanism of the Biuret Reaction*

(Mr. A. C. Jennings)

Jennings has recently described an improved procedure for the estimation of the protein content of barley grain by a modified biuret reaction. The method is sufficiently reliable for cereal breeding programmes. Arising from these studies, the conditions necessary for formation of the copper-protein chelate is being investigated. It has been found that the formation of the copper-protein chelate is dependent on pH, formation increasing with pH, with increasing liberation of H^+ until the reaction reaches virtual completion at

approx. pH 12.5. It has been found that cobalt and nickel also form coloured chelates with proteins, but the reactivity of these chelates with the Folin phenol reagent was found to be less than that of the copper chelate. The formation of copper chelates with simple ligands such as ethylenediamine, ethylenediamine tetracetic acid, glycylglycine, glycine and sodium potassium tartrate have also been studied. Important differences were found between the absorption by these chelates at 350 m μ and that of the copper, cobalt and nickel chelates with protein, the absorption of the former being much lower at this wavelength. The absorption spectra of the copper chelates of these simple ligands were found to alter with pH.

The results indicate that no single structure may be ascribed to the product but that several different chelate species are formed. The spectral absorption curve of the colour formed in the reaction between copper and protein would appear to be a summation of the spectral absorption curves of the several different chelate structures involved. The chemical reactivity of these different chelates is also being investigated, but as yet the results obtained are of a preliminary nature only.

(b) *Methods for Determining Availability of Phosphorus Compounds in Soil.*

(Mr. A. C. Jennings and Mr. J. K. Powrie (Agronomy Department))

A study of available phosphorus in soil was commenced and several methods of extraction of phosphorus from soil were investigated to determine the most suitable method for use in a subsequent field survey. In the particular soil type being studied under different phosphate regimes, a different proportion of the total phosphorus was extracted by each method, but in every method there was a high degree of correlation between extracted phosphorus and total phosphorus.

Plant Physiology

As was foreshadowed in the previous report, research activities in Plant Physiology have continued in the following fields: growth regulators, carbohydrate metabolism, and the influence of drought on the development of cereals. The horticultural programme has been augmented by the recent appointment of a second lecturer to specialise in this field, and a study of flower and fruit development is emerging as the main theme of this part of the Department's work. The provision of a post-doctoral fellowship for starch studies under a grant from the Wheat Research Council will enable this part of the programme to be resumed during 1960.

1. GROWTH-REGULATORS

(a) *Studies on the Responses of Sour-sob to Growth-regulators*

Dr. N. G. Marinos has continued his investigations into the high tolerance of sour-sob (*Oxalis pes-caprae*) to weedicides of the growth-regulator type. Earlier work had indicated that, although experiments with isolated leaf tissue supported the proposal that deactivation of the weedicide 2,4-D may occur in the leaf, a response to treatment with 2,4-D was also apparent in the subsequent germination behaviour of bulbs. Thus it became of some importance to determine the distribution of this weedicide within the plant following foliar application. To this end 2,4-D labelled in the carboxyl group with radioactive carbon

was applied, and after varying times samples of the different plant parts were taken for examination. Autoradiographs revealed that radioactivity quickly spread through the entire plant. Analyses of ethanol extracts of plant "tops" were made and ^{14}C was identified in two sub-fractions of the ethanol extract: the acid-ether fraction, in a form similar to chemically pure 2,4-D; and the acid-ethyl acetate fraction, in several different substances at least two of which behaved as if comprising 2,4-D complexes. In addition, an appreciable amount of radioactivity was insoluble in ethanol, and some escaped as respiratory carbon dioxide. Further detailed work is clearly desirable, and provided that satisfactory techniques for the determination of radioactivity in a large number of different substances can be evolved, possibly using the scintillation counting technique, the metabolic fate of applied 2,4-D will be examined more closely.

(b) *Root Contraction in Sour-sob*

In the previous report the contraction of the tuberous root, and the dependence of this process on the aerial parts of the plant, were mentioned. Subsequently, some microscopic observations made by Dr. Marinos confirmed an interesting phenomenon; alternating bands of turgid and collapsed cells were distributed throughout the length of the contracting sections of the tuberous root. In view of recent hypotheses concerning the role of calcium in regulating the physical properties of cell walls, it was decided to supply radioactive calcium to roots of sour-sob and follow its distribution. As a result, ^{45}Ca was found to accumulate in the zones of collapsing cells, and this preferential accumulation took place from an early phase of cell collapse onwards. Another investigation of turgid and collapsed cells has involved an examination of cell wall structure with the aid of an electron microscope. This study was undertaken during a visit by Dr. Marinos to Zurich in 1959. Unfortunately, little light was shed on the mechanisms regulating cell behaviour by this work, and an attempt was made to compare the micro-structure of cytoplasm from these two kinds of cell. Here again little progress has been achieved, largely as a result of technical difficulties associated with fixation procedures, and accordingly a study of alternative techniques is in progress.

(c) *The Inhibition of Root Growth*

The growth substance indole-acetic acid has a stimulatory effect on most growth processes so far studied, but its effect on root growth is predominantly one of inhibition. Preliminary studies conducted by Dr. L. G. Paleg suggest that several of the degradation products of indole-acetic acid, which appear in the root tissue after uptake of this substance has occurred, are firmly bound in the roots, whereas several others diffuse into the external medium. The initiation of biochemical reactions by these indolyl-compounds may play a part in inhibiting root elongation, and closer examination of these substances is, therefore, being attempted with the aid of new spectrophotometric equipment.

(d) *Inter-relationships Between Growth-regulators*

Certain growth processes occurring in the vegetative period of development are known to be influenced by both indole-acetic acid and gibberellic acid, whereas the interrelationships between these two substances in controlling flowering responses are largely unknown. An initial survey by Dr. Paleg revealed that temperature probably influences the action of gibberellic acid alone, and in combination with indole-acetic acid. Further, the effectiveness

of gibberellic acid in inducing flowering is reduced by indole-acetic acid. Additional information is required before the implications of these findings can be fully appreciated.

2. GROWTH STUDIES ON CEREALS

(a) *Responses to Drought*

During the period under review, Dr. D. Aspinall has continued analysing results from an experiment on the effect of time of commencement of droughting on the growth and maturation of barley plants. The details of this experiment were presented in the previous report, together with data collected to determine which component of yield was mostly influenced by the droughting treatments. Fresh weight, dry weight and volumes of grains collected at two-day intervals between anthesis and maturity have now been measured. The earlier droughting treatments (beginning before maximum grain dry weight was reached) terminated grain development (in terms of dry weight) at an earlier stage than in those grains not subjected to drought. However, the treatments had no appreciable effect on the drift of grain moisture content with time, and although a relationship between moisture content of grain and relative growth rate of grain can be established, there is no evidence that this is a causal one. The influence of droughting treatments has also been studied in relation to the subsequent germination behaviour of the grain, especially the germination capacity (defined as the percentage of grain germinating within seven days) and the germination rate (calculated from the number of grains germinating each day over a total of seven days). A drought at anthesis reduced the germination capacity when this was tested three months after harvest, but after twelve months little or no effect of the droughting treatment was evident. The rate of germination was reduced by droughting treatments applied not only at anthesis but also at other times, and, furthermore, rate of germination did not change with prolonged storage. It appears, therefore, that there is some difference between the mechanisms controlling germination capacity and germination rate.

Experience gained from the experiment just described has led Dr. Aspinall to explore two different avenues of approaching technical problems associated with the application of water stress. Firstly, to increase the precision of the data collected some experiments have been carried out in a controlled-environment cabinet. Secondly, to enable the effects of droughts of longer duration (comparable to that under field conditions) to be studied, six concrete lysimeters (each measuring 5 ft. $\times$ 3 ft. $\times$ 4 ft.) have been installed in a glasshouse. Provision has been made in these lysimeters for scanning the moisture contents of the soil at various depths with a neutron moisture meter, and thus attention has been paid not only to the growth and subsequent germination of grains from droughted plants, but also to the pattern of water utilization from the soil. Much of the data collected from the first lysimeter experiment still awaits final collation, but some preliminary observations may be recorded. Soil moisture stress was applied throughout two prolonged periods in the development of the barley plant; from emergence to heading, and from heading onwards. Grain size was appreciably reduced by water stress during the second period, but germination of the grain was most severely affected by the earlier period of drought. However, further time must elapse before all the germination tests necessary to elucidate the nature of the drought effects can be completed.

Physiological differences between varieties in response to drought have not been widely studied. To enter this field of research Mr. P. B. Nicholls has selected two varieties of barley, having approximately the same flowering date and time of maturation and showing certain differences in the field under conditions of water stress. He has subjected these two varieties to short periods of water stress in pots at the following times: shortly after germination, during differentiation of floral organs, and shortly after anthesis. One variety produced lower yields following drought at the two later stages of development, whereas the other was not affected significantly by any treatment. The various components which together make up yield of grain are now being examined to explore this differential response more fully.

(b) *Tillering*

Tiller emergence can be separated into three phases: an early phase, from seedling emergence to heading, when tillering is rapid; a middle phase, during heading, when few tillers emerge; and a late phase, during the final stages of ripening, when a large number of small tillers appears. Mineral nutrition is one factor known to influence the tillering of cereals, and it may be argued that fluctuations in competition for nutrients between tillers at the various growth stages lead to the pattern of phasic development just described. On this basis Dr. Aspinall has conducted several experiments in which mineral nutrients have been applied at various times, and the results have emphasized the dominant role that nutrition plays in the control of tillering. The onset of tiller flushes can be induced at any stage of barley growth by the addition of abundant nutrients, and, moreover, plants maintained continuously under a high level of nutrient supply do not show the three phases of tiller production described above. Factors other than nutrition, however, play a part in determining tiller development, and it is now known that during the final phase, when ears on the primary tillers are ripening, the number of tillers elongating can be increased by removing existing ears. Moreover, this increase can be inhibited by the application of indole-acetic acid to the decapitated stem. It is planned to extend these investigations to examine what must be a whole complex of interactions between nutrition, the effect of the apex, and competition between tillers, and to include lower-tillering varieties, which may exhibit a higher degree of apical control, in the hope of obtaining useful supplementary information.

3. CARBOHYDRATE METABOLISM

(a) *Assay Method for Reducing Sugars*

The most common test for reducing sugars employs an alkaline copper reagent while citric acid is commonly used as a buffer for enzyme reactions in which changes in amounts of reducing sugars are measured. Following careful observations made in connection with some anomolous results, Dr. L. G. Paleg undertook an examination of the effects of citric acid on the reducing sugar test, and showed an interference by this acid in the colorimetric estimation of reducing sugars by the Somogyi-Nelson method. The interference is thought to be due to a replacement of tartrate in copper-tartrate complexes and to the lessened sensitivity of the copper-citrate complex to reduction by sugars. An account of this work has been published.

(b) *Responses of Barley Endosperm to Gibberellic Acid*

As forecast in the previous report, most of the increased respiration that follows the addition of various respirable materials to barley endosperm is now known to be attributable to bacterial activity. A technique to eliminate bacterial contamination has been developed by Dr. Paleg, thus permitting work on the normal and gibberellic acid-induced metabolism of barley endosperm to proceed. After sterilization, the endosperm tissue is placed in water containing various concentrations of gibberellic acid, and at predetermined times samples of the surrounding medium are removed for examination. Analyses of sugars released indicate that the increase in sugar following treatment is a quantitative rather than a qualitative one, and since the response occurs over a hundred-thousand-fold range of gibberellic acid concentration, it is concluded that the effect is either directly or indirectly on enzymic activity. Investigations are being extended to include the effects of buffers, pH, and inhibitors, because these may reveal new information on both gibberellic acid effects and the biochemical reactions taking place in the endosperm during germination.

(c) *Carbon Fixation in the Barley Ear*

Application of the ear shading technique to awnless, single-awned and triple-awned varieties of barley by Dr. L. H. May and Mr. M. S. Buttrose led to significant reductions in yield of 9, 23 and 18 per cent. respectively, although the separate reductions were not significantly different from each other. Accordingly, these results allow only the claim that ears make a significant contribution to yield, and, moreover, these estimates of the magnitude of this contribution are somewhat lower than some made by workers elsewhere. However, an alternative technique was developed, and preliminary estimates put the possible ear contribution at a much higher level, about 50-60 per cent. Following further experiments conducted at Zurich in Switzerland, these high estimates were confirmed, and a detailed account of the work published. The new technique involves a reduction in the amount of substrate available for ear development from the remainder of the plant, and a reduction in the number of grains per ear, so that varying levels of competition for available substrate exist. Under these conditions the contribution of photosynthesis in the ear can be assumed to stand at its maximum value. Clearly, further work is required to resolve the discrepancy between results obtained by the two different methods.

(d) *Synthesis of Starch Granules*

Other studies by Dr. May and Mr. Buttrose have confirmed that two distinct types of starch granule are deposited in barley endosperm. Relatively small numbers of the first type are initiated in the first two weeks after flowering, and these granules continue to grow throughout the development of the endosperm. Large numbers of the second type of granule appear between 18-30 days after anthesis, but these grow little in size. There is a linear relationship between starch granule volume and endosperm volume throughout the complete period of endosperm development. Other interrelationships such as those between starch granule weight and volume, and also endosperm dry weight and volume, were examined, and these suggest that both starch granules and endosperm tissue increase in density with time. Further work depends on the development of more refined techniques for microscopic examination, and these are

being explored by Mr. Buttrose during a period of post-graduate study under Professor Frey-Wyssling in Switzerland.

4. NUTRITION

(a) *Nutritional Studies on Potatoes*

In experiments referred to in the previous report, it was found that symptoms of nutritional leaf roll similar to those occurring in the field could be induced in potatoes grown in pots in the glasshouse by supplying a high level of nitrogen as ammonium sulphate and a low level of potassium. During the period under review the suitability of the water culture method has been examined by Mr. G. R. Edwards, and his work has confirmed that potatoes can be grown satisfactorily in a container of vermiculite suspended over a conventional water culture solution.

Nitrate and ammonium sources of nitrogen have been compared and leaf rolling and premature plant collapse were found only in ammonium fed plants, as is the case on the light podsolized sands of the South-East of South Australia. The symptoms, however, were rather more severe than those observed in the field, and it may be that the virtual absence of nitrate ions in culture solution is responsible. Marked differences were also noted in the volume, amount and macroscopic appearance of roots from plants grown with the different sources of nitrogen.

In experiments involving the factorial combination of high and low levels of ammonium, potassium, and iron, field experience was again reproduced. High levels of potassium delayed the occurrence, and reduced the severity, of foliar symptoms associated with a high level of ammonium ions, although iron treatments were inconclusive. The water culture technique is to be continued since it will permit further study of this problem under much closer control than has been available in the past.

5. FLOWER AND FRUIT DEVELOPMENT IN HORTICULTURAL CROPS

(a) *Apples*

In 1959 Mr. Edwards began an investigation of the processes involved in the initiation of flowers in apples. Certain characteristics of apple spurs, taken from parts which had flowered and fruited, flowered but not fruited, and neither flowered nor fruited, are being compared since it is known that flower initiation occurs in these spurs at low, medium and high levels respectively. At a series of harvest dates samples of leaves and fruits are being taken for subsequent assay of naturally occurring growth-regulating substances, and on these same occasions growth measurements are also being made.

(b) *Other Crops*

Fruit set and development in several crops, such as grapes, tomatoes and almonds are also under examination with the aid of techniques developed by a recently appointed member of staff, Dr. B. G. Coombe, during three years post-graduate study at Davis, U.S.A. It is anticipated that particular attention will be directed towards improved techniques of assay of gibberellic acid, and also those processes involved in the rapid increase of sugar at the mid-stage in the development of the grape berry.

Entomology

1. ADVISORY SERVICES

Advisory services in entomology were provided for the Departments of Agriculture, and Woods and Forests, as well as for the local quarantine authorities. Many private enquiries were also received and answered.

Because of unfavourable weather conditions, there were no large-scale outbreaks of the locust, *Chortoicetes terminifera* (Walk.), in the State during the two years under review.

In October, 1958, San José scale was discovered on pome and stone-fruit trees at Mypolonga. This is the first recorded occurrence of this insect in South Australia. It is a serious pest of many kinds of fruit trees in various parts of the world. Surveys are being undertaken by the Department of Agriculture to ascertain the extent of its distribution; in the meantime an eradication campaign is in progress in the areas known to be inhabited by the species.

The unusual weather conditions in 1959 were responsible for wide-spread outbreaks of the weed web-worm, *Loxostege affinitalis* (Led.). Although, as usual, the species fed chiefly on weeds, some local damage was done to lucerne crops.

The first recorded occurrence of Oriental fruit-moth, *Cydia molesta* Busck., was from peach trees at Renmark in August, 1959. This insect is native to certain areas of Asia, and has been introduced into the U.S.A., where, in many parts, it is a major pest. It is also established in Victoria and New South Wales. Peaches and other stone-fruits, as well as several kinds of pome fruits, are liable to infestation. As a result of study of the conditions under which the species can flourish, control measures were devised which, it is believed, will minimize damage done by this insect.

For the first time since 1951, no outbreak of either Queensland or Mediterranean fruit-fly occurred in South Australia during the summer of 1959.

Surveys of the various forest areas in South Australia have been made to ascertain their insect populations. Knowledge, so obtained, is a necessary preliminary before any counter measures against harmful species can be adopted.

During 1959, the European earwig, *Forficula auricularia* L., was twice intercepted by officers of the Department of Agriculture in potatoes from Victoria. The insect has, more recently, been found to have established itself in the Mount Gambier district.

2. RESEARCH

The research activities of the Department for the years 1958-59 are outlined below:

(a) Pasture Insects

(Mr. L. D. Crawford)

Study of the biology and control of the red-headed cockchafer, *Adoryphorus couloni* Burm., in the lower South-East was continued.

In spring, the adults mate in the soil. The females prefer moist soil for oviposition, though eggs are capable of developing even when soil-moisture content is low.

Rate of larval development is greatly influenced by the water content of, and the proportion of organic matter in, the soil. By autumn, most larvae are

in their third instar, and overwinter as such, but a proportion have not completed their second stadium by autumn and overwinter as second instars. This phenomenon causes overlap in development. When summer comes, larvae which overwintered in their third instar complete their development, but the adults remain in the soil till the following spring, when mating occurs and the biennial life-cycle begins again. Larvae which hibernate as second instars may require three years in which to complete their development.

In relatively dry soil, larvae can withstand considerable desiccation. First and second instars, particularly at high temperatures, develop more rapidly in drier soils, and although third instars tolerate a wide range of moisture levels in the soil, wet soils are deleterious to all stages.

Although development may be completed when humus is the only available food, in nature the larvae feed on living roots as well. Grasses, wheat, and the seedlings of cruciferous summer crops are particularly susceptible to damage.

B.H.C. incorporated in the soil gives the most efficient control of third larval instars. Surface applications of any insecticide give little or no control of the species.

(b) Orchard Insects

(Dr. D. A. Maelzer)

(1) Codling Moth (*Cydia pomonella* (L.)).

Emergences and flights of moths during the summers, 1957-58 and 1958-59, were found to be related to meteorological conditions. Moths from overwintering larvae emerged in larger numbers on days after a warm air-mass had been over Adelaide than on days after a cold air-mass had been so located. The physiological ages of moths caught in traps during the summer suggested that emergences of moths of the summer generations (non-diapausing) were similarly affected.

The discovery that certain insecticides used for the control of codling moth were more toxic to adults than to young larvae, has led, in conjunction with the above data, to a more rational system of control. The chemicals were applied to coincide with expected peaks of moth emergence predicted from daily synoptic weather charts. This procedure gave excellent control.

Studies of the factors inducing diapause in codling-moth larvae are continuing.

(2) Mites

Preliminary observations have been made on the ecology of the tetranychid mites, *Aplonobia histricina* (Berlese), *Bryobia arborea* (M. & A.), and *Tetranychus telarius* Duges.

(3) Oriental Fruit-moth (*Cydia molesta* Busck.).

When Oriental fruit-moth was first discovered at Renmark, eradication was considered practicable only if the area of infestation were small. Later surveys, however, increased the known infested area thereby making attempted eradication inadvisable for the following reasons:

(i) Ecological considerations made it unlikely that the insect would become a serious pest in the Murray irrigation areas.

(ii) Eradication could be achieved only by the imposition of stringent eradication and quarantine measures whose enforcement would require a considerable annual expenditure over an indefinite number of years.

In view of these facts, a method of control was devised aimed at keeping the insect's numbers to an economic level.

(c) *Forest Insects*

(Dr. F. D. Morgan)

(1) The Scolytid Bark-Beetle, *Ips grandicollis* Eich.

An outbreak of this beetle occurred in Wirrabara Forest Reserve in 1959 on the perimeter of a recent forest fire. Salvage techniques were concentrated on trees carrying dense populations of beetles. The outbreak was brought under control by September. The work has given information on brood development, host suitability, behaviour of adults, and patterns of attack in relation to exposure of tree to sun. It has also shown that while outbreaks can be serious in particular circumstances, silvicultural control can minimize the effects. Studies are continuing on brood development and on natural-control factors.

(2) Other Pine-attacking Beetles

Incidental to the above study, information on the distribution and habits of three other species which attack pines has been obtained. These are *Hylastes ater* Payk., *Hylurgus ligniperda* F., and *Ernobius mollis* (L.).

(3) The Gum-leaf Skeletonizer, *Roeselia lugens* (Walk.)

The life-history of this species has been studied to enable more efficient insecticidal control measures to be undertaken when such are deemed necessary.

(4) Lerp Insects

There are several species of lerp insects which, at irregular intervals, almost defoliate eucalypts in different areas. Effective control measures cannot yet be devised since little is known of their respective biologies. Present work is directed towards making good part of this defect in knowledge.

(d) *Vine Insects and Mites*

(Mr. D. C. Swan)

(1) Study of the vine phylloxera as it occurs in north-eastern Victoria has been continued.

The insect remains stabilized in the area which it invaded many years ago. In these areas it has been found to present similar biological features to those displayed by it in Europe and North America; but under the climatic conditions which prevail where it occurs in Australia, its numbers may vary from heavy infestations to very low populations (under drought conditions). It is concluded that if present safeguards are maintained, the insect should not spread further in Australia. Uninfested regions, such as South Australia, will, however, be permanently subject to risk of invasion should infested rooted vines enter this State.

(2) Work has also continued on eriophyid mites, of which a varied native fauna is being recognised. These mites occur in Australia much as their relatives do in other continents. The economic species, however, which live on most fruit trees, are introduced species. A general account of these mites will be prepared in due course.

(e) *Scale Insects and White-flies*

(Miss Helen M. Brookes)

(1) Taxonomy of the scale insects (Coccoidea) has been continued with special attention to the mealy-bugs (Pseudococcidae). *Maconellicoccus* (= *Phenacoccus*) *hirsutus* (Green), the *Hibiscus* mealy-bug, was identified from specimens collected on cotton plants at Wyndham, Western Australia. This is the first record of its occurrences in Australia. A survey of the incidence of an

undescribed species of *Phenacoccus*, a pest of Gramineae in the U.S.A., showed the species to be widely but sparsely distributed in the wheat-growing areas of South Australia, where, however, it apparently does little or no damage. Study of the native genus *Epicoccus* is continuing.

(2) In 1958, San José scale, *Quadraspidiotus perniciosus* (Comst.), was recognised for the first time in South Australia, when it was found on stone-fruit and apple trees growing in irrigated citrus orchards at Mypolonga. Associated with it was an allied species, *Q. lenticularis* Lind., the presence of which in Australia had not previously been suspected. A taxonomic study of this genus in South Australia is in progress.

(3) A preliminary survey of the scale insects that produce leaf or stem galls on various species of eucalypts indicates that, in addition to those known, several undescribed species are also involved. Some of these cannot be assigned to any of the families of the Coccoidea as at present defined, and new families will need to be erected for their reception.

(4) Observations are continuing on the biology of the two species of white-fly, *Orchamoplatus citri* (Takahashi) and *Bemisia giffardi* (Kot.), mentioned in earlier reports.

(f) *Entomological Problems of Lucerne-seed Production*

(Mr. K. M. Doull and Mr. D. J. Taylor)

(1) The biology of *Heliothis punctigera* Wall. is being studied in detail. This species is one of the major pests of lucerne crops throughout the State. Caterpillar populations are often greatly reduced as a result of mass infection by a pathogenic micro-organism, the significance of which, as a potential agent of control, is being investigated.

(2) Field studies of the biology and ecology of *Etiella behrii* (Zell.) have been made. To relate seasonal activity to weather conditions, nightly catches of adults have been made for the past two years in light traps located in the grounds of the Waite Institute. Since the data obtained in 1958 were inadequate, the number of traps was increased to three in 1959. Recent laboratory and field experiments have been designed to ascertain the factors responsible for variations in numbers of natural populations of this species.

(3) Field experiments for the control of *H. punctigera* and *E. behrii* were continued. Based on experience and knowledge gained from limited trials made in 1958, large-scale tests were made in 1959 of two insecticides to compare their relative efficiencies in the control of *E. behrii*.

(4) Because inefficient pollination is still the major factor responsible for low seed yields, the behaviour of bees visiting lucerne flowers is being studied. A thorough understanding of such behaviour is essential before best use can be made of bees for pollination. Native solitary bees also play a part in pollination, and possible ways of increasing their effectiveness are being considered.

(5) Studies on the epizootiology of *Nosema apis* Zand. (Mr. K. M. Doull). *N. apis* has long been suspected of adversely affecting both the productivity and length of life of infested bees. No information on the distribution or ecology of the organism in Australia has been published. Work so far done suggests that, in Australia, seasonal variation in incidence of the disease, whether in individual hives or in the bee population as a whole, is not so clear-cut as reports from other countries make it appear to be. Some infestation is present in all hives at all times; the degree of infestation is determined by conditions, either inside or outside the hive, not necessarily related to the season.

Variations in proportions of bees infested are to be related to climate, nutrition and management. A thorough understanding of the host-parasite relationship is essential before any worth-while suggestions for dealing with the problem can be advanced. Factors affecting the natural tolerance of bees to the parasite are of importance and these are being investigated.

(g) *Aphid Investigations*

(Dr. B. Johnson)

(1) Parasitization of aphid nymphs causes them to acquire structural abnormalities. From a study of the developmental rates of host and parasite, evidence has been obtained which supports the hypothesis that the endocrine system controlling wing polymorphism is identical with that controlling metamorphosis.

(2) Times of determination and differentiation of various cuticular structures of aphids have been studied. The method used has been to transplant pieces of cuticle from one insect to another. Attention has been directed mainly to the antennal sensoria which are determined in the hypodermis probably at the time of the second moult, and are differentiated after two more moults, whether or not these are produced by a humoral environment favouring the differentiation of other alatiform structures.

(3) A study of the influence of ant-attendance on aphids has been made; when first and second alatiform nymphal instars are attended by ants, their development is diverted from the alate course and they become apterae. How this control is exercised is not yet known, though it may be through nutrition, since ant-attendance stimulates the aphids to imbibe more food.

(4) (Dr. B. Johnson and Mr. P. R. Birks.)

A theory of the nature of the developmental processes involved in the production of different forms of aphids has been developed. Based on experimental evidence, it is suggested that all female aphids begin development as presumptive alate sexuales. These can be diverted from this course to become either alate or apterous parthenogenetic females. The periods during which diversion can occur have been elucidated. This theory of diversion from a more primitive course of development has been extended to account for polymorphism in other groups of insects.

(5) (Mr. P. R. Birks.)

The influence of various environmental factors on the production of winged and wingless forms of *Aphis craccivora* Koch has been studied. It has been shown that the form of this species is influenced by host-plant condition, temperature, parentage, and crowding.

(h) *Salivary Physiology of Hemiptera and Homoptera; Red-Scale Investigations*

(Dr. P. W. Miles)

(1) Production of two types of saliva by *Aphis craccivora* Koch
(Homoptera)

When the aphid was anaesthetized with carbon dioxide and the stylets were removed from the rostrum and laid on a glass slide, two types of saliva were observed to be emitted from their tips when the insect resumed activity. These corresponded with the sheath-material and the watery saliva secreted by the Hemiptera (Heteroptera). Previously, the only type of saliva known to be secreted by aphids was the sheath material. The demonstration of a separate

watery secretion is of special interest in relation to the possible involvement of saliva in the transfer of viruses of the persistent-transmission type.

(2) Composition and Origin of Salivary Secretions of Hemiptera
(Heteroptera).

Histochemical tests on the salivary secretions and salivary glands of a number of local Hemiptera are continuing to be made. There is reason to believe that the secretions are fundamentally similar in all families of terrestrial, phytophagous bugs; further, their origins follow a similar pattern, modified by specific differences in complexity of the salivary apparatus. In general, sheath-material originates in the anterior, and, if present, the lateral parts of the gland; the watery saliva is secreted by the posterior part. The accessory gland produces an oxidase, and evidence has been obtained that this acts on the secretions of the main gland before they are discharged.

(3) Citrus red scale, *Aonidiella aurantii* (Mask.), has been established on citrus seedlings, and on potatoes, at the Waite Institute. The influence of predators or parasites or both on the development of scale populations is being investigated by examination of populations in the field, and by comparing the development on citrus trees of exposed and sheltered colonies.

(i) *The Arthropod Integument*

(Mr. H. F. Lower)

(1) Effects of Starvation on the Integument.

During starvation, the cuticle of the larva of *Persectania ewingii* (Wwd.) undergoes chemical and physical modification. A considerable part of its non-nitrogenous components is withdrawn, resulting in a marked change in the proportions of its water-extractable, alkali-extractable, and non-extractable fractions. On resumption of feeding, the original proportions are restored within 24 hours though no replacement of the normal storage occurs during this period. Starvation produces abnormalities in cuticular structure which often prevent completion of the development, even though the larva may apparently resume normal feeding for a time.

(2) The Apterygote Integument.

The integuments of two Apterygota—*Ctenolepisma longicaudata* Esch. and *Smynthurus viridis* L.—were investigated. Although both are primitive forms, their integuments are highly specialized. The hypodermis tends to be syncytial, its internal boundary often not being clearly demarcated from the other tissues. The cuticle of *Ctenolepisma*, though hardened, remains colourless; this is in contrast to the condition found in most insects, in which cuticular hardening is usually associated with a greater or lesser degree of colouration.

(3) Review.

A review of all work in print on the insect epicuticle up to the end of 1957 has been published. Consideration of all the evidence suggests that a fundamental change in current concepts of epicuticular structure is essential if the frequently-opposing views of workers are to be reconciled.

Acceptance of this change involves corresponding changes in the current terminology and such have accordingly been proposed.

Plant Pathology

As in previous years, an appreciation of the occurrence and severity of crop diseases throughout the State has been maintained through the advisory services to the State Departments of Agriculture and Woods and Forests. Quarantine inspections of imported plant material have been carried out and the facilities of the Department have been used for the introduction of potentially important propagating material of agricultural and horticultural crops.

Research investigations along lines indicated in previous reports have been continued with an emphasis on the study of soil-borne organisms. Some new projects arising from important disease problems in the State have been initiated.

1. ADVISORY SERVICES.

In cereal crops a strain of *Rhizoctonia solani* which attacks the coleoptiles, prior to, or immediately after, emergence of the seedlings, caused serious reduction in establishment in many of the lighter textured soils. Occasional instances had been observed in previous years, but the disease was widespread in 1958. Attack of cereal roots by the nematode *Heterodera avenae* was widespread in the same season and has become a limiting factor in the growing of oats in some districts.

Galling of the stems, leaves and inflorescences of subterranean clover by *Urophlyctis* sp. occurred commonly in the 1958 season and yields were further decreased from infection with clover stunt virus. Downy mildew of lucerne, *Peronospora trifoliorum*, continued to partially defoliate stands at certain times of the year, and early growth of some stands was markedly reduced through attack of the roots by the same strain of *Rhizoctonia solani* as attacks cereal roots. Unthrifty growth of many 3-4-year-old lucerne stands appears to be associated with rotting of the crowns, but the cause is not known. With considerable increases in the lucerne acreage these diseases require investigation.

Verticillium wilt was common in apricots and was recorded in trees 3-4 years out from the nursery. Root knot nematode, *Meloidogyne* spp. and root lesion nematode, *Pratylenchus* spp. were frequent on the roots of stone fruits in the irrigation areas, and with possible replanting of the older areas in the future these nematode populations present serious problems. Brown rot due to *Sclerotinia fructicola*, which has previously been severe in cherries in the Adelaide Hills, caused considerable losses in other stone fruits in irrigation districts in the last two years.

Potatoes, including varieties Sebago and Kennebec, grown in the Adelaide Hills in 1959 were attacked by *Phytophthora infestans*. Cross inoculation checks revealed the presence of different pathogenic strains of the fungus.

Black mould of roses due to *Chalaropsis thielavioides* was identified in 1959 as causing serious failure in borsault stocks in rose nurseries. Smut is widely distributed in couch grass in South Australia and in the spring of 1959 was responsible for distorted growth leading to bare patches in many lawns and playing fields in the metropolitan area.

2. LEGUME INOCULATION SERVICE.

(Dr. J. H. Warcup and Mr. S. R. Hockley)

Field trials carried out in conjunction with the State Department of Agriculture have confirmed the responses obtained in earlier trials from inoculation

of lucerne with *Rhizobium*. In these trials it was also shown that inoculated lucerne or clover established well on the deep sands in the South-East if lime was added at the time of seeding. Because of these results, together with the general increase in acreage sown to lucerne throughout the State, there has been an increasing demand for *Rhizobium* cultures for inoculating lucerne seed.

Field trials to determine the most effective strains of *Rhizobium* for the deep sands and other areas have been continued with measurement of responses in the second and third years after seeding. The difference between inoculated and uninoculated plants is usually greatest in the first year, gradually disappearing in subsequent years, but uninoculated plots often contain markedly fewer plants. Performance of the standard strains of *Rhizobium* distributed to farmers from the Institute was checked to ensure their effectiveness.

The drought conditions in 1959 rendered the field work almost valueless in that year.

3. RESEARCH.

(a) *Pellicularia* Investigations. (Dr. N. T. Flentje, Dr. A. Kerr and Mr. R. L. Dodman.)

Studies on the number and distribution of nuclei and their behaviour during growth have continued. In *Pellicularia filamentosa* there appear to be in the growing tip eight nuclei which congregate and divide simultaneously at a definite stage of elongation of the cell, eight daughter nuclei migrating to the back of the cell and eight to the tip followed by the formation of a septum. Cell division and mode of branching follows a regular pattern. Mature cells usually contain eight nuclei except in small side branches in the older part of the mycelium which may contain 2-4 nuclei. Such cells when obtained from macerated cultures give rise to a wide range of culture types which differ in growth rate, mode and regularity of branching, etc., and many of which sector freely, but have the same pathogenicity as the parent culture.

In *Pellicularia praticola* the number of nuclei in tip cells is less regular, as is also the septum formation and mode of branching, but the actual progress of nuclear division is similar to that in *P. filamentosa*. Present evidence suggests, however, that the number of nuclei per cell is less than in *P. filamentosa*.

The influence of root exudates from several hosts in inducing the formation of infection cushions prior to penetration of these hosts has been further studied using various strains of *P. filamentosa*. Different exudates specifically stimulate different strains, which stimulation in general parallels the specificity in pathogenicity of the strains. A colorimetric method was developed for quantitatively assaying the stimulation obtained. The stimulation by radish root exudate of the radish infecting strain of *P. filamentosa* has been used for detailed study. In collaboration with Dr. M. R. Atkinson chemical substances causing specific effects on growth rate and type of branching of the fungus have been isolated from the exudate and purified. It appears probable that a derivative of nicotinic acid may be involved, but that more than one substance is necessary for infection cushion formation. Further bioassay methods using strips of epidermis and cuticle are being developed.

(b) *Fusarium Wilt of Peas*. (Dr. A. Kerr, Mr. M. V. Carter, and Mr. J. Nath.)

Crosses between the American pea variety, New Era, which is resistant to *F. oxysporum* f. *pisi* race 2 and locally-grown susceptible varieties, Greenfeast and Victory Freezer, have been made and homozygous wilt-resistant lines of Greenfeast have been selected from the fourth back cross generation. Sample lots of seed have been field-tested for their resistance to other forms of root rot while further selection for desirable horticultural qualities is being carried out.

The effect of soil fumigation with Vapam on the general micro-flora of the soil and *Fusarium* spp. in particular was studied. Reductions in population of *Fusarium* varied markedly according to the method of application of Vapam, but even in the most effective treatments rapid recolonization by *Fusarium* occurred and such treatment was not feasible economically as a control of *Fusarium* wilt.

(c) *Studies in Verticillium alboatrum*.

(1) Antagonistic Soil Bacteria. (Dr. A. Kerr.)

During a period at the Botany School, Cambridge organisms antagonistic to *V. alboatrum* were isolated from the surface of tomato roots growing in natural untreated soil. Of fifteen isolates, ten were identified as *Pseudomonas fluorescens*, two as *Streptomyces* spp. and three were unidentified species of bacteria. The degree of antagonisms of the isolates was measured *in vitro* and one isolate of *P. fluorescens* was selected for further detailed study. Tomato seeds and the roots of young seedlings were inoculated with this isolate. The seeds and seedlings were then placed in untreated soil and the population of the inoculated antagonist on the roots was determined at weekly intervals. Although high numbers were recorded after one week, the population fell rapidly and after two weeks and four weeks with seed and root inoculation respectively, there was no difference in number of antagonists on roots of inoculated and uninoculated plants. Inoculations of tomato seedlings with several of the antagonists separately did not reduce infection by *V. alboatrum*.

(2) *Verticillium* wilt of Stone Fruits. (Dr. N. T. Flentje, Dr. J. H. Warcup and Mr. J. B. Taylor.)

Isolates of *Verticillium* from soil, virgin and cultivated, and from diseased trees, have been studied and the presence of several species has been confirmed by overseas authorities. *V. alboatrum* occurs commonly in cultivated soils in South Australia in association with stone fruit trees. This fungus has been shown to grow through non-sterile soil and colonize, in competition with other soil organisms, sections of autoclaved tomato stems. It has readily invaded 1-2-year-old apricot trees, suggesting that nursery trees may become infected, but there appear to be certain periods of the year when the fungus cannot be readily reisolated from infected trees.

(d) *Urophlyctis* on Subterranean Clover. (Mr. B. G. Clare.)

Using techniques based on those outlined by Dr. J. S. Karling in the United States, resting sporangia of *Urophlyctis* were readily germinated.

Field and laboratory infection studies were carried out using a variety of hosts, but in no case did infection of lucerne occur, whereas under identical conditions infection of subterranean clover readily took place. The fungus appears to be a strain of *Urophlyctis alfalfa* which attacks only subterranean clover.

(e) *Asochyta Diseases of Peas.* (Mr. M. V. Carter and Mr. W. J. Moller.)

Field investigations have shown that *Mycosphaerella pinodes* is the main organism causing leaf and pod spot of peas in South Australia.

This fungus remained viable in dry stored pea straw throughout twelve months and readily ejected viable ascospores when wetted. Ascospore discharge failed to occur from infected straw which had been buried for six days in warm, moist soil, but ascospores appeared to develop into chlamydospores which were still capable of infecting plants. Chemicals sprayed on to straw which successfully eradicated the fungus in laboratory tests failed to give satisfactory results in the field.

Spore trappings throughout the growing season in selected pea crops showed a slow build-up of ascosporic inoculum in the early stages of the crop, probably arising from perithecia in straw from the previous crop. Later in the season a very rapid build-up occurred. This appeared to be associated with the development of perithecia in leaf lesions of the growing crop.

Detailed studies of the influence of temperature and moisture on ascospore discharge from infected straws have been made using a wind tunnel and the effect of solar radiation on the viability of the spores has been investigated.

(f) *Studies on the Microflora of South Australian Soils.* (Dr. J. H. Warcup.)

(1) Sporulation of Soil Basidiomycetes.

Studies on the production of fructifications from cultures of soil Basidiomycetes have continued. Certain species investigated were found to require relatively high temperatures (about 70° F.) for fruitbody production, others fruited only at lower temperatures (60° F.).

(2) Activity of Fungi in Wheatfield Soil.

As a further development of the programme to investigate the activity of fungi in soil, a study of the fungi, saprophytic and parasitic, growing on and in wheat roots has been commenced. This work will continue until the roots have finally decomposed.

(g) *Mycology.* (Mr. B. G. Clare.)

Compilation of a catalogue of Australian fungi is proceeding. Specimens from the Herbarium have been loaned to different authorities with a consequent checking of previous determinations.

The Herbarium, which has been enriched by additions from Professor Cleland's personal collection, has been named the J. B. Cleland Mycological Herbarium, in recognition of Professor Cleland's outstanding work.

A comprehensive survey of the *Erysiphaceae* in Australia has been carried out and a number of powdery mildews recorded for the first time in Australia.

(h) *Virus Investigations.* (Dr. N. C. Crowley.)

(1) Transmission of Vine Virus Diseases.

The commonly used vine virus indicator variety, St. George, which is phylloxera resistant, has been introduced for use in investigating virus diseases present in South Australia. Other commonly used indicator varieties are not Phylloxera resistant and cannot be introduced, but seedlings of a variety of *Vitis labrusca* are being used as substitute. Cuttings from local commercial lines of sultana, riesling, sherry and grenache are being tested as indicators. A field trial to determine the effect of boron and potassium application on vines is

being carried out at four locations because the virus disease, yellow vein, which produces symptoms similar to boron deficiency, is suspected in several areas.

(2) Stone Fruit Virus Investigations.

During the autumn and winter the herbaceous host range used by Fulton for the identification of stone fruit viruses was used to identify some of the viruses isolated from cherries in South Australia. One isolate was found to correspond closely with Fulton's virus "B" which is probably prune dwarf virus. One other isolate does not correspond with any of the isolates described by him. The use of these herbaceous hosts has proved to be most valuable in the comparison of local diseases with those recorded overseas, but even in a cooled glasshouse the work can be done only during the cooler months. The indicator varieties, Shiro plum, Tilton apricot, Non Pareil almond, Elberta peach, Sam, Van, Bing, Montmorency and Lambert cherries, have all been imported from the Irrigation Research Station at Prosser, Washington, and are being increased for propagation on stocks now being grown in the field. It will be possible to use a very limited amount of this material as indicator stocks during 1960.

(3) Seed Transmission of Plant Viruses.

While at the University of Wisconsin during 1958 the opportunity was taken to continue these investigations with a number of viruses that do not occur in Australia. A study was made of the time of embryo infection using a tobacco ringspot virus in soy beans: barley stripe mosaic virus in barley and southern bean mosaic virus in beans. From the results of these studies it has been concluded that the inability of plant viruses to infect meristematic tissues is one of the main reasons for the rarity of seed transmission of plant virus diseases.

(i) *Nematology Investigations.* (Mr. J. M. Fisher.)

A preliminary survey of phytoparasitic nematodes present in South Australian agricultural areas has been completed and a number of major problems has been revealed.

Methods of surface sterilization of nematodes were investigated as a preliminary to laboratory investigations on pathogenicity. The microflora of the alimentary tract as well as the external surface was studied. There was no significant microbiological content of the alimentary tract and surface sterilization in sterile water with added detergent finally provided a satisfactory method of obtaining sterile nematodes. Because of the differences between genera the appropriate concentration of detergent is critical.

During the survey high populations of *Paratylenchus hamatus* were found in soil associated with plants not recorded as susceptible hosts. The population of this nematode in the soil of both irrigated and non-irrigated orchards was followed closely throughout most of the year.

The nematodes were isolated and surface sterilized and their pathogenicity was tested by transferring them on to the roots of different host plants growing aseptically in various synthetic media. While the nematodes developed satisfactorily, considerable difficulty has been experienced in growing the host plants satisfactorily on these media, and they have not been maintained longer than six weeks.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at two centres: at the Waite Institute itself and at Yudnapinnae (50 miles north-west of Port Augusta). Observations are made daily at 0900 local time. The records for 1958 and 1959, with climatological summaries are given in Tables I to IV.

WAITE INSTITUTE (34° 58'S., 138° 38'E. Height 402 ft.)

Table I. Records for 1958 and 1959.

(a) Monthly rainfall and evaporation, number of wet days, mean relative humidity, and mean hours of bright sunshine per day.

Month	Rainfall (in.)		Number of days with ≥ 0.04 in. rain		Evaporation (in.)		Relative humidity 0900 local time		Hours of bright sunshine per day	
	1958	1959	1958	1959	1958	1959	1958	1959	1958	1959
January	0.23	0.09	2	1	8.76	9.64	47	41	10.2	11.2
February	0.13	1.38	1	4	7.18	6.98	47	53	9.4	8.5
March	1.08	1.35	3	4	6.09	6.58	50	53	7.4	8.2
April	0.62	0.38	1	3	5.01	4.41	48	51	7.7	6.7
May	5.52	0.35	18	2	2.33	3.00	74	59	3.0	4.8
June	0.47	0.64	3	3	2.16	2.30	64	63	4.7	4.2
July	4.16	1.93	16	9	1.66	1.71	77	69	3.3	3.0
August	3.11	2.42	15	10	2.20	2.93	74	64	4.2	4.7
September	3.85	1.69	15	7	2.53	3.53	67	59	4.6	5.6
October	3.79	0.98	19	8	3.80	5.17	67	55	5.0	7.2
November	0.52	1.14	7	5	5.73	7.49	57	44	7.5	8.3
December	0.29	2.52	4	10	7.22	6.61	51	55	8.7	7.3
Year	23.77	14.87	104	66	54.67	60.35	60	55	6.3	6.6

(b) Mean of daily air temperatures; and extreme air temperatures

Month	Mean daily				Mean $\frac{1}{2}$ (Max. + Min.)		Highest		Lowest	
	Maximum		Minimum		1958	1959	1958	1959	1958	1959
	1958	1959	1958	1959						
January	80.6	86.3	59.5	63.1	70.0	74.7	99.6	108.3	52.0	51.0
February	81.9	80.5	61.9	62.2	71.9	71.3	96.3	101.8	53.0	53.8
March	75.1	78.6	58.8	60.5	67.0	69.5	92.9	93.0	51.0	54.2
April	74.6	72.7	56.9	56.2	65.8	64.4	92.0	85.8	48.2	47.1
May	65.4	65.8	54.7	50.3	60.0	58.1	71.9	74.9	48.2	39.9
June	58.2	61.0	44.9	48.1	51.6	54.5	67.8	68.0	35.4	39.0
July	56.9	58.3	45.4	45.8	51.1	52.1	63.0	65.0	37.6	36.7
August	58.5	63.1	47.5	50.4	53.0	56.8	68.2	72.0	41.0	42.2
September	59.9	64.4	47.4	49.3	53.7	56.9	72.3	79.8	41.0	42.0
October	64.4	69.2	51.5	52.7	58.0	60.9	82.0	82.8	44.0	44.0
November	73.8	80.1	55.4	59.6	64.6	69.8	94.8	101.7	42.9	46.0
December	74.1	72.3	54.6	55.5	64.3	63.9	96.3	90.7	45.0	48.4
Year	68.6	71.0	53.2	54.5	60.9	62.7	99.6	108.3	35.4	36.7

(c) Mean of daily soil temperatures ($^{\circ}\text{F}$) at 1 inch, 6 inches, 12 inches and 24 inches.

Month	1 in. Maximum		1 in. Minimum		6 in. Maximum		6 in. Minimum	
	1958	1959	1958	1959	1958	1959	1958	1959
January	112.9	122.2	63.0	65.6	87.0	90.7	71.5	74.7
February	112.2	107.5	63.0	64.5	86.0	85.3	71.4	71.7
March	94.8	104.0	59.8	62.5	77.7	82.3	66.1	69.3
April	86.1	86.4	56.0	55.2	72.7	72.6	62.2	61.5
May	68.5	76.8	53.6	48.1	62.4	64.0	57.7	54.9
June	62.2	68.3	43.8	44.6	55.2	58.0	49.2	50.3
July	59.6	65.5	44.4	43.4	53.3	55.8	48.4	48.9
August	64.2	72.0	47.4	47.8	57.0	60.2	51.4	52.4
September	68.9	79.8	47.3	47.8	59.2	64.6	51.9	54.5
October	75.2	91.5	52.1	53.3	64.6	71.9	56.9	59.6
November	98.6	108.6	58.5	58.9	78.4	82.5	64.9	67.6
December	107.4	95.1	58.5	57.4	82.4	77.2	67.5	64.3
Year	84.2	89.8	53.9	54.1	69.7	72.1	59.9	60.8

Month	12 in. Maximum		12 in. Minimum		24 in. Maximum		24 in. Minimum	
	1958	1959	1958	1959	1958	1959	1958	1959
January	79.4	81.9	73.6	76.5	71.7	73.4	71.0	72.6
February	78.7	78.3	73.5	74.0	72.2	72.4	71.4	71.6
March	72.3	75.7	69.1	71.4	68.8	70.1	68.2	69.4
April	67.8	67.9	64.6	64.3	64.9	65.0	64.3	64.5
May	60.7	60.5	59.1	57.7	60.1	59.3	59.8	58.9
June	53.1	54.6	51.4	52.4	53.7	54.4	53.3	54.0
July	50.9	52.7	49.5	50.6	50.6	52.1	50.3	51.8
August	54.2	56.1	52.6	53.8	53.0	53.5	52.6	53.1
September	55.8	59.7	53.5	56.5	53.6	56.6	53.0	56.0
October	60.9	65.3	58.4	61.3	57.4	59.9	56.9	59.3
November	71.4	74.7	66.6	69.3	64.1	67.0	63.3	66.1
December	74.7	71.4	69.7	66.8	67.7	66.3	67.1	65.6
Year	65.0	66.6	61.8	62.9	61.5	62.5	60.9	61.9

(d) Mean wind speed at 1.25 metres and 2 metres (miles per day)

Month	1.25 Metres		2 Metres	
	1958	1959	1958	1959
January	84	78	97	93
February	75	75	90	88
March	76	69	90	83
April	69	54	83	66
May	77	46	95	57
June	52	61	64	75
July	70	52	87	64
August	84	88	101	105
September	69	73	85	87
October	90	85	110	100
November	77	84	94	99
December	78	89	94	104
Year	75	71	91	85

Table II *Climatological Summaries 1925-59.*

Month	Rainfall (ins.)	Days with ≥ 0.04 in. rain	Evapora- tion (in.)*	Relative Humidity 0900 L.T.	Saturation deficit (in mercury) 0900 L.T.	Hours bright sunshine per day	Wind speed (miles per day)†	
							1.25 metres	2 metres
January	0.90	3.0	8.39	46	.428	9.1	86	100
February	1.06	3.1	6.89	50	.381	8.7	80	93
March	0.83	3.1	6.25	50	.357	7.7	75	88
April	2.07	7.4	3.89	60	.229	5.7	71	84
May	3.08	9.9	2.45	67	.158	4.1	65	77
June	3.05	11.3	1.69	74	.106	3.3	64	76
July	3.25	13.4	1.63	75	.093	3.2	66	80
August	2.93	12.4	2.22	71	.119	4.4	80	94
September	2.40	9.9	3.16	63	.173	5.7	77	92
October	2.21	9.2	4.44	59	.220	6.5	82	98
November	1.54	6.0	5.77	53	.299	7.7	83	99
December	1.19	4.8	7.34	48	.375	8.3	84	99
Year	24.51	93.5	54.12	60	.245	6.2	76	90

* Mean for 1935-59.

† Mean for 1950-59.

TABLE II (continued)

Month	Air temperatures (°F)						
	Average daily			Average Monthly		Extreme	
	Max.	Min.	Mean	Max.	Min.	Highest	Lowest
January	81.7	60.5	71.1	101.3	49.9	111.8	46.7
February	80.8	60.8	70.8	98.7	50.4	105.7	44.1
March	78.2	59.4	68.8	95.3	48.6	105.2	42.8
April	70.4	54.6	62.5	85.4	45.7	94.3	41.5
May	64.1	50.8	57.4	75.7	42.7	82.4	34.8
June	59.0	46.9	52.9	66.4	39.3	77.1	33.7
July	57.2	45.3	51.3	64.9	38.6	72.3	32.5
August	59.2	46.0	52.6	69.3	38.7	78.4	33.7
September	63.7	48.3	56.0	78.6	39.7	88.4	33.7
October	68.0	50.9	59.5	86.4	42.0	94.3	38.8
November	73.8	54.5	64.1	93.6	44.0	101.7	40.0
December	78.3	57.8	68.0	99.3	47.1	107.8	41.8
Year	69.5	53.0	61.3	103.6††	37.1††	111.8	32.5

†† Average annual max. and min. temperatures.

Month	Soil temperatures (°F) Average daily							
	1 inch		6 inches		12 inches		24 inches	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	109.1	63.9	85.5	71.4	78.2	73.0	73.1	71.3
February	106.0	63.6	84.3	70.9	77.9	72.8	73.7	71.9
March	99.6	61.1	79.8	68.0	74.7	70.1	71.7	69.9
April	81.9	54.9	69.2	60.6	66.5	63.4	66.2	64.5
May	69.4	49.9	60.9	54.6	59.8	57.5	60.7	59.2
June	62.8	46.4	55.5	50.4	54.8	52.8	55.8	54.7
July	60.8	45.1	53.6	48.5	52.6	50.6	53.3	52.3
August	64.3	46.2	55.9	50.0	54.0	52.0	53.9	52.7
September	73.2	49.2	61.9	53.7	58.5	55.3	56.9	55.5
October	82.6	53.5	68.7	58.4	63.9	60.1	61.2	59.6
November	94.2	58.2	76.6	63.9	70.0	65.4	66.0	64.2
December	103.1	62.0	82.2	68.6	74.9	69.9	70.3	68.4
Year	83.9	54.5	69.5	59.9	65.5	61.9	63.6	62.0

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(32° 8' S., 137° 10' E., Height 435 ft.)

TABLE III

Records for 1958 and 1959

(a) Monthly rainfall (in.), number of wet days and mean relative humidity.

Month	Rainfall		Number of days with ≥ 0.04 inches of rain		Relative humidity (0900 local time)	
	1958	1959	1958	1959	1958	1959
January	0.17	0.64	2	3	39	34
February	0.03	0.76	0	4	39	45
March	1.39	1.09	3	4	50	49
April	0.42	0.00	1	0	45	45
May	0.74	0.90	4	2	73	50
June	0.00	0.14	0	1	56	67
July	1.54	1.22	6	6	69	69
August	2.36	0.08	8	1	71	57
September	1.77	0.17	9	2	61	46
October	1.41	0.55	7	4	53	41
November	0.47	0.53	3	3	49	30
December	0.40	0.44	3	3	39	40
Year	10.70	6.52	46	33	54	48

(b) Mean of daily air temperatures; and extreme air temperatures (°F)

Month	Mean Daily				Mean		Highest		Lowest	
	Maximum		Minimum		$\frac{1}{2}(\text{Max.} + \text{Min.})$					
	1958	1959	1958	1959	1958	1959	1958	1959	1958	1959
January	84.7	95.6	63.6	65.4	74.1	80.5	105.0	111.0	57.2	57.1
February	91.9	90.3	63.8	63.8	77.9	77.1	105.6	104.2	55.0	51.5
March	81.5	87.9	58.9	61.8	70.2	74.8	95.5	100.0	50.0	51.0
April	80.5	80.7	55.3	53.9	67.9	67.3	96.0	92.8	47.8	43.0
May	71.1	69.7	50.4	47.1	60.8	58.4	83.8	81.4	40.0	40.0
June	62.3	63.8	40.5	41.9	51.4	52.8	77.0	77.4	29.6	31.2
July	60.9	60.8	40.9	40.7	50.9	50.7	68.0	67.6	29.2	30.6
August	62.2	69.2	45.1	46.0	53.7	57.6	75.2	83.6	34.8	36.8
September	65.1	73.0	45.4	48.3	55.3	60.7	80.0	88.6	35.6	37.4
October	74.0	79.3	50.5	53.6	62.2	66.5	92.4	95.5	40.0	42.6
November	84.0	89.6	56.9	60.2	70.5	74.9	103.5	109.0	44.5	48.5
December	84.3	84.1	58.5	57.0	71.4	70.6	100.2	101.8	49.0	47.0
Year	75.2	78.7	52.5	53.3	63.9	66.0	105.6	111.0	29.2	30.6

IV *Climatological summaries, 1939-59.*

Month	Rainfall (ins.)	Days with ≥ 0.04 in. rain	Evaporation (in.)*	Relative Humidity 0900 L.T.	Saturation deficit (in mercury) 0900 L.T.	Mean daily soil temperatures (°F)†			
						1 inch		12 inches	
						Max.	Min.	Max.	Min.
January	0.62	1.7	14.52	43	.510	114.8	66.7	90.8	79.7
February	0.97	2.1	11.48	48	.424	109.0	65.2	89.2	77.9
March	0.62	1.9	10.34	49	.369	104.5	60.5	85.8	74.7
April	0.50	2.0	6.69	57	.237	88.4	53.0	75.8	65.7
May	0.95	3.3	4.25	68	.141	76.6	47.3	67.4	57.6
June	0.93	3.8	2.61	77	.084	66.2	42.0	61.1	50.6
July	0.89	4.5	2.93	76	.078	66.9	40.8	58.5	47.9
August	0.67	3.8	4.09	68	.123	73.0	44.2	61.4	51.6
September	0.48	3.2	6.44	54	.222	84.0	49.9	68.4	58.2
October	0.87	3.6	8.81	48	.304	92.4	55.8	75.0	63.6
November	0.65	2.9	11.09	44	.401	102.4	61.1	81.9	69.9
December	0.73	2.4	13.19	40	.492	114.7	65.3	87.9	76.7
Year	8.88	35.2	96.44	56	.282	91.1	54.3	75.3	64.5

*Mean for 1939-54

†Mean for 1946-54

TABLE IV (continued)

Month	Air Temperatures (°F)					Extreme		Wind speed (miles per day) at 2 metres. *
	Average Daily			Average Monthly				
	Max.	Min.	Mean	Max.	Min.	Max.	Min.	
January	92.0	63.6	77.8	109.0	53.3	117.0	39.2	167
February	89.6	63.4	76.5	105.2	53.8	111.4	48.8	166
March	85.6	59.0	72.3	99.4	48.4	108.8	40.5	130
April	76.1	52.1	64.1	91.5	42.7	98.7	36.0	102
May	68.6	46.5	57.6	82.0	36.2	88.2	27.3	79
June	62.8	41.8	52.3	72.1	32.3	77.6	24.0	76
July	61.2	39.4	50.3	70.9	30.8	79.0	21.4	77
August	65.6	41.3	53.5	78.2	32.7	87.8	26.4	93
September	72.0	45.2	58.6	87.4	35.9	96.8	28.8	111
October	77.2	50.8	64.0	95.2	40.0	106.0	35.5	118
November	84.0	56.1	70.1	102.2	44.8	110.6	40.3	133
December	89.0	60.1	74.6	107.0	49.2	114.0	35.0	141
Year	77.0	51.6	64.3	111.0**	29.6**	117.0	21.4	117

**Average annual max. and min. temperatures.

*Mean for 1951-54

Publications of the Staff of the
Waite Agricultural Research Institute
University of Adelaide, 1958-1959

I. FIELD CROPS, PASTURES AND FORAGE PLANTS

- K. Abele (1959).—Cytological Studies in the Genus *Danthonia*. *Trans. Roy. Soc. S. Aust.*, 82: 163-173. (Reprint 751.)
- W. G. Alden (1959).—The Summer Nutrition of Weaner Sheep: The Relative Roles of Available Energy and Protein when Fed as Supplements to Sheep Grazing Mature Pasture Herbage. *Aust. J. agric. Res.*, 10: 219-236. (Reprint 732.)
- K. P. Barley (1958).—The Influence of Earthworms on Soil Fertility. I. Earthworm Populations Found in Agricultural Land near Adelaide. II. Consumption of Soil and Organic Matter by the Earthworm *Allolobopha caliginosa* (Savigny). *Aust. J. agric. Res.*, 10: 171-178; 179-185. (Reprint 731.)
- , (1958).—Earthworm Populations Found near Adelaide and Their Influence on the Fertility of the Soil. Ph.D. Thesis, Univ. of Adelaide.
- K. P. Barley and A. C. Jennings (1959).—Earthworms and Soil Fertility. III. The Influence of Earthworms on the Availability of Nitrogen.
- K. P. Barley (1959).—IV. The Influence of Earthworms on the Physical Properties of a Red-Brown Earth. *Aust. J. agric. Res.*, 10: 364-370; 371-376. (Reprint 753.)
- K. P. Barley and A. L. Tidsall (1959).—Effects of Flood Irrigation and Plant Growth on Two Riverine Soils. *Aust. J. agric. Res.*, 10: 510-517. (Reprint 762.)
- K. P. Barley and R. H. Sedgley (1959).—The Influence of Grass Roots on the Conduction of Water through Coarse-Textured Soils. *Soils and Ferts.*, 22: 155-156. (Reprint 764.)
- J. N. Black (1958).—Competition between Plants of Different Initial Seed Size in Swards of Subterranean Clover (*Trifolium subterraneum* L.) with Particular Reference to Leaf Area and the Light Microclimate. *Aust. J. agric. Res.*, 9: 299-318. (Reprint 704.)
- , (1956).—Light Intensity and Plant Growth. Arid Zone Research, Climatology and Microclimatology. Proc. Canberra Symposium: 178-180. (Reprint 770.)
- , (1959).—On the Light Microclimatology of Pastures. *Kungl. Skogs-och Lantbruksakademiens Tidskrift Årg. 98*. (Reprint 773.)
- , (1959).—Seed Size in Herbage Legumes. *Herb. Abstr.*, 29: 235-241. (Reprint 778.)
- , (1958).—The Growth of a Clover Sward. Proc. Univ. Nottingham, Fifth Easter School in Agric. Sci., 295-307. (Reprint 789.)

- C. M. Donald and J. N. Black (1958).—The Significance of Leaf Area in Pasture Growth. *Herb. Abstr.*, 28: 1-6. (Reprint 708.)
- C. M. Donald (1958).—The Interaction of Competition for Light and for Nutrients. *Aust. J. agric. Res.*, 9: 421-435. (Reprint 710.)
- C. M. Donald and C. H. Williams (1954).—Fertility and Productivity of a Podzolic Soil as Influenced by Subterranean Clover (*Trifolium subterraneum* L.) and Superphosphate. *Aust. J. agric. Res.*, 5: 664-687. (Reprint 712.)
- C. M. Donald and W. G. Allden (1959).—The Summer Nutrition of Weaner Sheep: The Deficiencies of the Mature Herbage of Sown Pasture as a Feed for Young Sheep. *Aust. J. agric. Res.*, 10, 199-218. (Reprint 733.)
- C. M. Donald (1959).—The Production and Life Span of Seed of Subterranean Clover. *Aust. J. agric. Res.*, 10, 771-787. (Reprint 767.)
- H. S. Hawkins and J. N. Black (1958).—Competition between Wheat and Three-cornered Jack. *Aust. Inst. Agric. Sci.*, 24: 45-50. (Reprint 697.)
- H. V. Jenkins (1959).—An Airflow Planimeter for Measuring the Area of Detached Leaves. *Plant Physiol.* 34: 532-536. (Reprint 768.)
- R. J. Millington (1958).—Soil Structure Aeration and Seedling Growth. Ph.D. Thesis, Univ. of Adelaide.
- , (1959).—Establishment of Wheat in Relation to Apparent Density of the Surface Soil. *Aust. J. agric. Res.*, 10: 487-494. (Reprint 761.)
- R. H. Sedgley and K. P. Barley (1958).—Effects of Root Growth and Decay on the Capillary Conductivity of a Sandy Loam at Low Soil-moisture Tension. *Soil Sci.*, 86, 175-179. (Reprint 724.)
- C. G. Stephens and C. M. Donald (1958).—Australian Soils and Their Responses to Fertilizers. *Adv. in Agron.*, 10: 167-256.

II. AGRICULTURAL CHEMISTRY

- C. A. Appleby and R. K. Morton (1959).—Lactic Dehydrogenase Cytochrome b_2 of Baker's Yeast. Purification and Crystallization. *Biochem J.*, 71: 492-499. (Reprint 746.)
- , (1959).—Lactic Dehydrogenase and Cytochrome b_2 of Baker's Yeast. Enzymic and Chemical Properties of the Crystalline Enzyme. *Biochem. J.*, 73: 539-550. (Reprint 777.)
- M. R. Atkinson, Eleanor Johnson and R. K. Morton (1959).—Equilibrium Constant of the Galactokinase Reaction and Free Energy of Hydrolysis of Adenosine Triphosphate. *Nature, Lond.*, 184: 1925-1927. (Reprint 776.)
- Margot J. Baillie and R. K. Morton (1958).—Comparative Properties of Microsomes from Cow's Milk and from Mammary Gland. I. Enzymic Activities. *Biochem. J.*, 69: 35-44. (Reprint 714.)
- , (1958).—Comparative Properties of Microsomes from Cow's Milk and from Mammary Gland. II. Chemical Composition. *Biochem J.*, 69: 44-53. (Reprint 715.)

- R. J. Best (1958).—Virus Nucleoproteins. *Roy. Aust. Chem. Inst. Proc.*, 25: 258. (Reprint 713.)
- , (1959).—Exchange of Determinants between Strains of Tomato Spotted Wilt Virus. *IX Internat. Bot. Congr. Proc.*, II, IIA. (Reprint 769.)
- M. D. Hatch, Judith A. Pearson, Adele Millerd and R. N. Robertson (1959).—Oxidation of Krebs Cycle Acids by Tissue Slices and Cytoplasmic Particles from Apple Fruit. *Aust. J. biol. Sci.*, 12: 167-174. (Reprint 774.)
- R. K. Morton (1958).—Enzymic Synthesis of Coenzyme I in Relation to Chemical Control of Cell Growth. *Nature, Lond.*, 181: 540-542. (Reprint 706.)
- , (1958).—The Phosphotransferase Activity of Phosphatases. I. Spectrophotometric Methods for the Estimation of Some Phosphate Esters and other Compounds. *Biochem. J.*, 70: 134-139. (Reprint 721.)
- , (1958).—The Phosphotransferase Activity of Phosphatases. II. Studies with Purified Alkaline Phosphomonoesterases and some Substrate-specific Phosphatases. *Biochem. J.*, 70: 139-150. (Reprint 722.)
- , (1958).—The Phosphotransferase Activity of Phosphatases. III. Comparison of Enzymic Catalysis by Acid Phosphatase with Non-enzymic Catalysis at Acid pH Values. *Biochem. J.*, 70: 150-155. (Reprint 723.)
- , (1958).—The Cytochromes. *Rev. Pure Appl. Chem.*, 8, 161-220. (Reprint 743.)
- J. P. Quirk and J. L. Davidson (1959).—Effect of Electrolyte Level of the Irrigation Water on the Establishment of Pasture on Riverina Clay. *Aust. J. Sci.*, 21, 191-192. (Reprint 754.)
- G. E. Rogers and D. H. Simmonds (1958).—Content of Citrulline and other Amino Acids in a Protein of Hair Follicles. *Nature, Lond.*, 182: 186-187. (Reprint 742.)
- D. H. Simmonds (1958).—Automatic Equipment for Determination of Amino Acids Separated on Columns of Ion Exchange Resins. *Analyt. Chem.*, 30: 1043-1049. (Reprint 738.)
- D. H. Simmonds and J. J. Bartulovich (1958).—The Amino Acid Composition of Fractionated Cortical Cells from Wool. *Text. Res. (J)*, xxviii: 378-381. (Reprint 739.)
- D. H. Simmonds (1958).—The Amino Acid Composition of Keratins. Part V. A Comparison of the Chemical Composition of Merino Wools of Differing Crimp with that of other Animal Fibres. *Text Res. (J)*, xxviii: 314-317. (Reprint 740.)

III. PLANT PHYSIOLOGY

- M. S. Buttrose and L. H. May (1958).—Physiology of Cereal Grain. I. The Source of Carbon for the Developing Barley Kernel. *Aust. J. biol. Sci.*, 12: 40-52. (Reprint 736.)
- W. J. Lovett and L. H. May (1958).—The Metabolism of Tobacco Leaves during Flue-curing. *Aust. J. Sci.*, 20: 237. (Reprint 718.)

- W. J. Lovett (1959).—Studies on the Metabolism of Detached Tobacco Leaves. I. The Influence of Potassium Nutrition on the Growth of Tobacco and the Quality of Cured Leaf. *Aust. J. agric. Res.*, 10: 27-40. (Reprint 735.)
- N. G. Marinos (1958).—The Control of Soursob (*Oxalis pes-caprae*) with Vapam. *J. Aust. Inst. agric. Sci.*, 259-261. (Reprint 719.)
- , (1958).—Moleic Hydrazide in the Control of the Bulbous Weed *Oxalis pes-caprae*. *Nature, Lond.*, 181: 1143. (Reprint 734.)
- L. H. May and J. L. Davidson (1958).—The Role of Carbohydrate Reserves in Regeneration of Plants. I. Carbohydrate Changes in Subterranean Clover following Defoliation. *Aust. J. agric. Res.*, 9: 767-777. (Reprint 726.)
- L. H. May and M. S. Buttrose (1959).—Physiology of Cereal Grain. II. Starch Granule Formation in the Developing Barley Kernel. *Aust. J. biol. Sci.*, 12: 146-159. (Reprint 750.)
- L. Paleg and D. Aspinall (1958).—Inhibition of the Development of the Barley Spike by Gibberellic Acid. *Nature, Lond.*, 191: 1743-1744. (Reprint 725.)
- L. Paleg and R. M. Muir (1959).—Short Communications. Neutral and Acid Auxins in Developing Tobacco Fruit. *Aust. J. biol. Sci.*, 12: 340-343. (Reprint 759.)
- L. Paleg (1959).—Citric Acid Interference in the Estimation of Reducing Sugars with Alkaline Copper Reagents. *Analyt. Chem.*, 31: 1902-1904. (Reprint 772.)

IV. MYCOLOGY AND PLANT PATHOLOGY

- M. V. Carter (1959).—Chemical Destruction of Mature Perithecia of *Mycosphaerella pinodes*. *Nature, Lond.*, 183: 162-163. (Reprint 737.)
- N. C. Crowley (1958).—The Use of Skim Milk in Preventing the Infection of Glasshouse Tomatoes by Tobacco Mosaic Virus. *J. Aust. Inst. agric. Sci.*, 24: 261-263. (Reprint 720.)
- , (1959).—Studies on the Time of Embryo Infection by Seed Transmitted Viruses. *Virology*, 8: 116-123. (Reprint 755.)
- Dorothy I. Fennell and J. H. Warcup (1959).—The Ascocarps of *Aspergillus alliaceus*. *Mycologia*, LI: 409-415. (Reprint 784.)
- N. T. Flentje (1957).—Studies on the *Pellicularia filamentosa* (Pat. Rogers). III. Host Preparation and Resistance and Strain Specialization. *Trans. Brit. mycol. Soc.*, 40: 322-336. (Reprint 711.)
- C. G. Hansford (1957).—Tropical Fungi VIII. *Sydowia* XI: 1-6. (Reprint 709.)
- A. Kerr (1958).—The Use of Cellophane in Growth Studies on Soil Fungi. *Trans. Brit. mycol. Soc.*, 41: 14-16. (Reprint 745.)
- J. H. Warcup (1959).—Studies of Basidiomycetes in Soil. *Trans. Brit. mycol. Soc.*, 42: 45-52. (Reprint 748.)

V. ENTOMOLOGY

- B. Johnson (1958).—Influences of Parasitization on Form Determination in Aphids. *Nature, Lond.*, 181: 205-206. (Reprint 696.)
- , (1958).—Factors Affecting the Locomotor and Settling Responses of Alate Aphids. *Animal Behaviour*, VI: 9-26. (Reprint 716.)
- , (1958).—Embryonic Cuticle in Aphids. *Aust. J. Sci.*, 21: 146. (Reprint 749.)
- , (1959).—Effect of Parasitization by *Aphidius platensis* Bréthes on the Developmental Physiology of its Host, *Aphis craccivora* Koch. *Ent. exp. and appl.*, 2: 82-99. (Reprint 763.)
- , (1959).—Studies of the Degeneration of the Flight Muscles of Alate Aphids. II. Histology and Control of Muscle Breakdown. *J. ins. Physiol.*, 3: 367-377. (Reprint 780.)
- H. F. Lower (1958).—The Integuments of Two Apterygota—*Ctenolepisma longicaudata* (Thysanura : Lepismatidae) and *Smynthurus viridus* L. (Collembola : Smynthuridae). *J. Morph.*, 103: 331-351. (Reprint 747.)
- , (1959).—The Chemical Components of the Test of an Australian Lac Insect, *Austrotachardia acaciae* (Maskell). *Trans. Roy. Soc. Sth. Aust.*, 82: 175-181. (Reprint 752.)
- , (1959).—Some Effects of Starvation on the Larval Cuticle of *Persectania ewingii* (Wwd.) (Lepidoptera : Nectuidae). *Amer. Midl. Nat.*, 61: 390-398. (Reprint 757.)
- , (1959).—The Insect Epicuticle and its Terminology. *Anns. ent. Soc. Amer.*, 52: 381-385. (Reprint 765.)
- , (1959).—Ants and Form Reversal in Aphids. *Nature, Lond.*, 184: 740-741. (Reprint 775.)
- P. E. Madge (1958).—The Ecology of *Oncopera fasciculata* (Walker) (Lepidoptera : Hepialidae) in South Australia. V. Changes in the Environment of *O. fasciculata* Associated with the Development of County Grey for Agriculture. *Aust. J. Zool.*, 6: 19-26. (Reprint 705.)
- P. W. Miles (1958).—Contact Chemoreception in some Heteroptera, Including Chemoreception Internal to the Stylet Food Canal. *J. ins. Physiol.*, 2: 338-347. (Reprint 741.)
- , (1959).—Secretion of Two Types of Saliva by an Aphid. *Nature, Lond.*, 183: 756. (Reprint 756.)
- F. D. Morgan (1959).—The Ecology and External Morphology of *Stolotermes ruficeps* Brauer (Isoptera : Hodotermitidae). *Trans. Roy. Soc. N.Z.*, 86: 155-195. (Reprint 744.)

VI. CLIMATOLOGY

- J. W. Holmes and A. F. Jenkinson (1959).—Techniques for Using the Neutron Moisture Meter. *J. agric. eng. Res.*, 4: 100-109. (Reprint 760.)

VII. MISCELLANEOUS

- R. J. Best (1958).—Preface and Preliminaries to "Introducing South Australia". ANZAAS and Melb. Univ. Press, v-vi. (Reprint 717.)
- , (1958).—Scientific Research: A Brief Survey. (Extract from "Introducing South Australia"). ANZAAS and Melb. Univ. Press, 287-291. (Reprint 727.)
- , (1958).—Pre-school Education. (Extract from "Introducing South Australia"). ANZAAS and Melb. Univ. Press, 149-155. (Reprint 728.)
- C. M. Donald (1958).—The Pastures of South Australia. (Extract from "Introducing South Australia".) ANZAAS and Melb. Univ. Press, 149-155. (Reprint 729.)
- J. Melville (1958).—Agricultural Research. (Extract from "Introducing South Australia".) ANZAAS and Melb. Univ. Press, 305-315. (Reprint 730.)
- , (1959).—Chemistry and the Future of Agriculture. *Proc. Roy. Aust. Chem. Inst.*, 26: 524-533. (Reprint 771.)
- R. J. Millington and J. P. Quirk (1959).—Permeability of Porous Media. *Nature, Lond.*, 183: 387-388. (Reprint 758.)
- R. J. Millington (1959).—Gas Diffusion in Porous Media. *Science*, 130: 100-102. (Reprint 766.)

Records of Field Experimental Work

I. PERMANENT ROTATION EXPERIMENT, 1926-1959 (C1)

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per acre: Sepoy wheat (1926-34), Seewari (1935-47), Seewari 48 (1948-59), 80-90 lb; Early Burt oats, 60-70 lb; Prior barley, 70-80 lb.; White Brunswick peas, 120-150 lb.; Wimmera rye-grass, 10-15 lb. (1926-45), and Wimmera rye-grass, 3 lb. + Fulghum oats, 40 lb. (1946-59) on rotations wheat, pasture, fallow and wheat, oats, pasture, fallow; Wimmera rye-grass, 3 lb. + subterranean clover, 6 lb. on the rotations wheat, 2 years pasture and wheat, 2 years pasture, fallow; phalaris, 3 lb. + subterranean clover, 6 lb. + lucerne, 1 lb. + Wimmera rye-grass, $\frac{1}{2}$ lb. on the rotations wheat, wheat, 4 years pasture and the permanent pasture.

Basal dressing of superphosphate, 187 lb, per acre (1929-43), 94 lb, per acre (1944-59).

Design: Unreplicated, but each course of each rotation is represented each year.

Area of each plot = $1/7$ acre (1926-37), $1/7 \cdot 619$ acre (1938-59).

Total yields are based on air-dry weights of harvested crops and oven-dry weights of forage crops.

TABLE I.

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1958 AND 1959, AND OVER THE DURATION OF THE EXPERIMENT. FIGURES IN BRACKET INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE.

1958	Rotation	Grain, Bushels per acre				Total produce, cwt. per acre*			
		Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas
	Wheat, fallow	32.0	—	—	—	49.0	—	—	—
	Wheat, peas	27.4	—	—	31.3	36.3	—	—	39.1
	Wheat, barley, peas	47.1	25.3	—	34.0	68.4	34.2	—	64.7
	Wheat, oats, fallow	44.8	—	29.3	—	65.8	—	31.4	—
	Wheat, pasture, fallow	53.8	—	—	—	72.1	—	—	—
	Wheat, 2 years pasture:	35.4	—	—	—	49.7	—	—	—
	1st year	—	—	—	—	—	—	—	36.8
	2nd year	—	—	—	—	—	—	—	46.7
	Wheat, 2 years pasture fallow: 1st year	49.3	—	—	—	75.2	—	—	38.2
	2nd year	—	—	—	—	—	—	—	85.8
	Wheat, oats, pasture, fallow	55.8	—	33.1	—	76.6	—	36.6	66.0
	Wheat, wheat 4 years pasture	27.6	—	—	—	61.9	—	—	49.1
	1st year	22.2	—	—	—	55.2	—	—	48.2
	2nd year	—	—	—	—	—	—	—	53.0
	3rd year	—	—	—	—	—	—	—	62.0
	4th year	—	—	—	—	—	—	—	78.3
	Wheat continuously	10.3	—	—	—	24.4	—	—	—
	Permanent pasture	—	—	—	—	—	—	—	118.1

* Air-dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 1 (continued).

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1958 AND 1959, AND OVER THE DURATION OF THE EXPERIMENT. (FIGURES IN BRACKET INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE.)

1959	Rotation	Grain, Bushels per acre				Total produce, cwt. per acre*			
		Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas
Wheat, fallow		3.7	—	—	—	5.9	—	—	—
Wheat, peas		3.6	—	—	0.5	9.0	—	—	6.4
Wheat, barley, peas		7.4	7.2	—	2.7	13.4	8.1	—	7.2
Wheat, oats, fallow		6.9	—	—	—	14.2	—	—	—
Wheat, pasture, fallow		6.2	—	5.3	—	9.2	—	5.6	—
Wheat, 2 years pasture:	1st year	6.6	—	—	—	10.9	—	—	—
	2nd year	—	—	—	—	—	—	—	11.5
Wheat, 2 years pasture, fallow:	1st year	8.5	—	—	—	15.3	—	—	7.6
	2nd year	—	—	—	—	—	—	—	13.7
Wheat, oats, pasture, fallow		10.6	—	8.8	—	17.1	—	6.7	—
Wheat, wheat, 4 years pasture:	1st year	3.0	—	—	—	6.6	—	—	8.9
	2nd year	2.7	—	—	—	8.2	—	—	18.0
	3rd year	—	—	—	—	—	—	—	30.0
	4th year	—	—	—	—	—	—	—	18.1
Wheat continuously		0.8	—	—	—	5.8	—	—	23.4
Permanent pasture		—	—	—	—	—	—	—	31.6

* Air-dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 1 (continued).

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1958 AND 1959, AND OVER THE DURATION OF THE EXPERIMENT. FIGURES IN BRACKET INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE.)

Mean Yield to 1959		Grain, Bushels per acre				Total produce, cwt. per acre*			
Rotation		Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas
Wheat, fallow		29.9(34)	—	—	—	43.9(34)	—	—	—
Wheat, peas		22.8(34)	—	—	17.5(32)	33.0(34)	—	—	26.7(34)
Wheat, barley, peas		27.1(8)	19.7(8)	—	15.3(8)	32.1(8)	21.2(8)	—	27.9(8)
Wheat, oats, fallow		31.5(33)	—	—	—	48.2(33)	—	—	—
Wheat, pasture, fallow		36.3(33)	—	—	—	50.5(33)	—	—	—
Wheat, 2 years pasture:	1st year	28.6(8)	—	—	—	35.1(8)	—	—	—
	2nd year	—	—	—	—	—	—	—	25.9(32)
Wheat, 2 years pasture fallow:	1st year	35.6(8)	—	—	—	47.2(8)	—	—	19.8(8)
	2nd year	—	—	—	—	—	—	—	40.5(8)
Wheat, oats, pasture, fallow		42.5(32)	—	—	—	60.2(32)	—	—	41.5(8)
Wheat, wheat 4 years pasture:	1st year	18.4(8)	—	43.6(32)	—	32.0(8)	—	40.4(32)	64.5(7)
	2nd year	14.3(7)	—	—	—	23.9(7)	—	—	28.7(32)
	3rd year	—	—	—	—	—	—	—	36.8(6)
	4th year	—	—	—	—	—	—	—	65.5(6)
Wheat continuously		12.3(34)	—	—	—	23.3(34)	—	—	64.7(6)
Permanent pasture		—	—	—	—	—	—	—	91.2(8)

*Air-dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 2.
YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS 1958 AND 1959. (OVEN-DRY WEIGHTS, CWT. PER ACRE).

1958	Rotation	Sown Species						Volunteer species		
		Total	W.R.G.	Sub. clover	Phalaris	Lucerne	Grazing oats	Annual legumes	Annual Grass	Miscel- laneous
1958	Wheat, pasture fallow	36.8	2.4	Tr.	—	—	33.8	0.5	—	0.1
	Wheat, 2 years pasture:	46.7	9.5	18.7	Tr.	Tr.	—	8.8	7.2	2.5
	2nd year	38.2	9.1	0.3	0.6	—	—	—	1.3	26.9
	Wheat, 2 years pasture fallow: 1st year	85.8	39.5	20.9	Tr.	0.9	—	1.2	20.7	2.6
	2nd year	66.0	40.3	17.6	1.2	0.5	—	—	6.1	0.3
	Wheat, oats, pasture, fallow	49.1	8.4	—	—	—	39.8	0.9	—	—
	Wheat, wheat 4 years pasture: 1st year	46.2	9.2	9.7	1.9	Tr.	—	1.5	21.7	2.2
	2nd year	53.0	5.6	7.7	6.5	—	—	—	17.3	15.9
	3rd year	62.0	1.9	3.8	21.1	0.4	—	0.1	29.1	5.6
	4th year	78.3	1.6	8.9	3.0	—	—	0.4	58.0	6.4
1959	Permanent pasture	118.1	Tr.	6.2	12.4	4.4	—	Tr.	91.4	3.7
	Wheat, pasture fallow	11.5	0.3	—	—	—	11.2	—	—	—
	Wheat, 2 years pasture:	7.6	0.3	—	—	—	—	—	7.3	Tr.
	2nd year	13.7	1.6	Tr.	Tr.	—	—	Tr.	5.4	6.7
	Wheat, 2 years pasture, fallow: 1st year	5.2	0.3	Tr.	—	—	—	0.2	4.6	0.1
	2nd year	27.8	12.6	2.6	1.3	Tr.	—	0.4	4.0	6.9
	Wheat, oats, pasture, fallow	8.9	Tr.	Tr.	—	—	8.6	0.2	—	0.1
	Wheat, wheat 4 years pasture: 1st year	18.0	1.4	Tr.	4.3	—	—	Tr.	16.6	Tr.
	2nd year	30.0	1.2	Tr.	—	—	—	—	22.7	1.8
	3rd year	18.1	1.0	Tr.	12.8	0.3	—	Tr.	0.8	3.2
	4th year	23.4	1.8	Tr.	7.4	—	—	Tr.	11.2	3.0
1959	Permanent pasture	31.6	0.4	—	3.4	5.0	—	Tr.	22.0	0.8

